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Industry Agenda

Bringing Space Down to Earth

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Bringing Space Down to Earth

Publication Preview

Once an exclusive resource, space-based technologies and their applications are now increasingly available to governments, businesses and civil society organizations. From monitoring human rights violations and the impacts of climate change to helping people find the fastest way home, space technologies are being applied in unexpected and innovative ways.

The World Economic Forum's Global Agenda Council on Space Security is publishing a book that breaks through the technical jargon and clearly explains how space-based technologies and services are crucial to face society's greatest challenges. In a straight-forward manner, the Global Agenda Council on Space Security aims to inform readers about a wide range of opportunities they may not have known were possible.

This pre-launch preview offers readers an overview of the book's content – 12 chapters spanning topics from food security and education, to disaster management and climate change.

Each chapter acts as a guide, summarizing the challenges humankind faces, the potential tools and solutions provided by space-based technologies and services, and case studies showing how these tools and solutions are already being applied.

Bringing Space Down to Earth will be serialized online and published as a book in 2014.

For more information on how to access the full publication please visit: wef.ch/space

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Foreword

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Space matters. Over the past five decades, space has been regarded as the future of humankind or a field of contest in the Cold War rivalry. Neither view is relevant today. Although the competitive nature of technological achievement and the wish to explore space will never end, the most vital role space plays today is as critical infrastructure for the world. This report, *Bringing Space Down to Earth*, addresses how important space is in our daily lives, particularly in times of crisis and challenge. It also shows why space and society's ability to use it must be protected from natural and man-made hazards.

Space is no longer a "big boys' club". Fifty-seven countries own and operate at least one satellite, while virtually everyone on Earth benefits from the services these orbiters provide. Space capabilities, for example, are crucial in response to humanitarian relief after natural disasters, including the recent typhoon in the Philippines. Space has become an indispensable infrastructure on which everyone relies.

Yet space of course offers benefits not just during such emergencies. Space activities provide vital information for education, food security, public health, water resource management, governance of the Arctic, nuclear security and human rights. Space-derived services not only improve the efficiency and effectiveness of many terrestrial pursuits but also deliver much of the knowledge and understanding needed to prevent and mitigate a variety of risks.

There are risks in space as well. As the importance of space increases, so too does the need to protect assets in it and the environment of space itself. The various hazards include debris, radio-frequency interference and weather that can damage or destroy satellites or make operating in space more costly. Asteroids, massive solar storms and other dangers could pose significant threats to life on Earth. The Chelyabinsk meteor that landed in Russia in February 2013 is a minor example.

This report, a collective effort of the Members of the World Economic Forum's Global Agenda Council on Space Security, highlights the key role that space plays in making the world safer, more secure and more prosperous. I recommend it to all who are interested in improving the efficiency and security of their daily lives. It reminds us that space is not about space per se but about humanity and the societies on our planet. It is time to *bring space down to Earth.*

Introduction: Space Matters

Snapshot

With US$ 304 billion in commercial revenue and government spending in 2012 and an average annual growth rate between 5% and 8%, space-related business is one of the fastest growing sectors in the world.

Space assets serve as an economic multiplier and enabler for many other sectors, including transportation, banking, telecommunications and Internet services, healthcare, agriculture and energy, among others.

Services provided by satellite are essential for much of modern infrastructure and scientific activities, such as water management systems (dams and irrigation), electric power grids, weather prediction and disaster monitoring/management, and climate change studies. Space-based systems are crucial for risk prediction and mitigation all around the globe.

Developing countries are increasingly seeking space assets in their quest for sustainable economic and social development. In particular, space activities contribute to science, technology, engineering and mathematics (STEM) education and the development of a highly skilled workforce.

Space programmes have produced technological spin-offs that have benefited civil society and the non-space commercial sector in many ways.

On Earth, space matters.

The Space Economy

Over the past eight years, the global economy grew by 85%, from US$ 164 billion in 2004 to US$ 304 billion in 2012.[1] The space sector is one of the fastest growing in the world, with average annual growth rates between 5% and nearly 8%. Overall, space-based infrastructure supports an ever-growing selection of downstream products and services across multiple users and markets. Not only wealthy nations are reaping these benefits: as global competitiveness expands and new satellite technologies become cheaper, developing countries are making the necessary investments in space with the goal of growing their economies.

In 2012, US government space-related spending on the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA) and the Department of Defense was US$ 48 billion. Other governments spent US$ 31 billion on their civil and military space organizations, led by Europe with US$ 5.1 billion for the European Space Agency (ESA), the Russian Federation with US$ 4.6 billion, Japan with US$ 4.4 billion, and China with US$ 3.1 billion.[2] And while commercial launch vehicle companies such as SpaceX and Orbital Sciences are beginning to enter the sector, the primary actors in space are, and shall for some time remain, governments.

But unlike in the past, space is not limited to the world's superpowers. The increase in the number of space-faring nations has been a major achievement of the past decade: today 57 countries have one or more satellites, up from only 26 in 2001. More and more governments view space as a worthwhile investment that can propel their national social, economic and technological development and safeguard national security.

Small companies and even individuals have also become important parts of the global space economy in recent years. The development of space tourism – human spaceflight undertaken by private individuals who purchased tickets, rather than professional, government-sponsored astronauts – has resulted in the injection of new money and fresh public attention to the space industry. Indeed, a single private company, Virgin Galactic, has already collected deposits from more than 650 future astronauts, dramatically eclipsing the total number of people who have even been to space (fewer than 550) and representing more than US$ 100 million in revenues. Similarly, the lower price points and more frequent flight opportunities offered by platforms ranging from commercially operated parabolic aircraft to reusable suborbital launch vehicles to orbital platforms such as CubeSats have encouraged a variety of entrants. Entities ranging from venture capital backed start-ups to successful R&D firms from adjacent industries are becoming customers of aerospace transportation and manufacturing firms.

Secondary Economic and Development Benefits

Space has a positive impact on many markets, adding value through applications ranging from telecommunications to earth observation. Benefiting are both buyers, ranging from governments to corporations, and users from the biggest cities in the United States to rural India.

A country's first investments in space are often focused on developing capabilities and are part of a larger national plan to improve information and communications technology (ICT), infrastructure, agriculture and education – all essential elements in building a resilient economy underpinned by sustainable development.

These investments are usually driven by a long-term strategy of progressive capability development, often not realized until a space programme reaches its second or third generation. Technology transfer plays an essential role, as it allows countries to develop its industrial and technological base by gaining knowledge and experience in satellite design, manufacturing and integration from experienced prime contractors.

In addition, as space programmes require a skilled technical workforce, space agencies and governments therefore invest in education and outreach programmes in schools from primary level through to universities. They often provide scholarships and internships to students to encourage them to enter the STEM fields. STEM education develops the advanced skills required for a competitive workforce that can generate economic growth.

Worldwide, the space sector employs an estimated 120,000 workers in Organisation for Economic Co-operation and Development (OECD) countries,[3] and 250,000 in the Russian Federation.[4] Due to technology spin-offs and the vast number of related space-enabled applications, employment in the STEM fields typically expands, further growing national wealth through the multiplier effects of indirect supply chains.

Earth observation satellites

Critical to these capabilities are Earth observation (EO) satellites. Data from EO satellites contribute to many activities, including improving agriculture and water management practices, monitoring disasters and relief operations, tracking refugee movements and settlements, predicting the weather, and national defence. The value chain for EO is less developed than that for communications satellites, but still generates significant commercial revenue. Total EO revenue from sales and value-added services by commercial operators was US$ 2.3 billion in 2012. The remote sensing market is expected to grow to US$ 6 billion by 2020 as nations use satellites for economic development. Between 2001 and 2010, 140 EO satellites from 26 countries were deployed on orbit. This number is expected to increase to 298 satellites from 43 countries by 2020.[5] Private industry is building and operating a growing number of these satellites.

Global navigation and positioning satellites

Space-based technologies have also revolutionized transportation and navigation, resulting in more efficient routes, better safety records and decreased operation costs. The key enabling technology is the Global Navigation Satellite System (GNSS), with the most prominent being the US Global Positioning System (GPS), the Russian Federation's GLONASS, Europe's GALILEO, China's BeiDou, the Quasi-Zenith Satellite System of Japan, and the Indian Regional Navigational Satellite System (IRNSS). This system of satellites has provided a flexible, accurate and low-cost method of tracking positions, planning routes and more precisely timing arrival and delivery schedules for ground, maritime and air transportation.

Ground transportation systems (trucking and rail) have long utilized GPS-based navigation and timing services for fleet management and planning schedules. Personal use of GPS by motorists has skyrocketed in recent years. The maritime industry, which relies heavily on communications satellites since landlines do not exist at sea, is now also adopting the technology. Common in railway operations today is GNSS usage in safety-critical devices supporting signalling (on both high- and low-density lines) and other applications, including asset management and passenger information. The aviation industry is the latest transportation sector to adopt the technology, prompted by safety concerns. Airlines are embracing satellite navigation services, which promise to cut costs and increase efficiency by improving flight path planning and traffic flow, enhancing the ability to land in bad weather and high-terrain, and reducing carbon dioxide emissions.

GNSS satellites have contributed to the development of efficient and lower-cost water management systems, for example, by providing precise timing for the working of dams and the routing and time management of electric power grids. As a result, developing countries are better able to afford investing in such large infrastructure projects.

The installed base of GNSS devices is just over a billion and is expected to rise to 7 billion by 2022 – almost one for every person on the planet. Growth rates are most remarkable outside Europe and North America. The global market for GNSS devices is expected to grow from slightly less than EUR 50 billion in 2012 to EUR 100 billion in 2019. But the wider market enabled by GNSS services is even higher – worth EUR 150 billion in 2012 and expected to grow to EUR 250 billion by 2022.[6]

Communications satellites

Communications satellites make up the bulk of satellites in orbit, providing television broadcasting, Internet services and telephony. Communications satellite services have helped underpin the information revolution, enabling long-distance communications in areas where laying cable is difficult due to terrain, distance and lack of infrastructure such as roads. The many benefits range from improved banking services to distance education and telemedicine. Communication satellites are also helping to bridge the digital divide between developed and developing nations by bringing Internet services to remote areas.

Satellite communications, the most commercially mature space industry, generate over US$ 100 billion in revenues worldwide, driven primarily by broadcasting services.[7]

Due to the globalization of the customer base, deregulation, technological advances and global economic growth, the satellite television industry has expanded significantly over the past two decades, with more than 25,000 digital TV channels available worldwide, compared to fewer than 800 analogue channels in 1991.[8] Demand is only growing.

By taking advantage of the existing assets of others, entrants in the space-based telecommunications business are paying lower costs. Countries, however, are seeing the benefit of having their own satellite to provide domestic telecom services. Abu Dhabi, Chile, Laos, Nigeria and others have applied to the International Telecommunication Union (ITU) to operate geosynchronous communications satellites over their territory and have begun placing contracts for manufacturing and launch services. Many of these nations have begun deregulating their telecommunications sector to stimulate business and consumer demand.

Technology Transfer and Commercial Spin-offs

Thousands of technologies used in the space sector – from rocket materials to astronaut life-support systems – have been successfully spun off for use in practical terrestrial applications. In fact, space agencies have created technology transfer programmes designed to facilitate this process and aid in the commercialization of such applications through licensing and industry partnerships. A significant number of modern industrial innovations have indeed come from the aerospace industry.

The need to miniaturize electronics in the 1960s for NASA's Apollo programme, the space sector laid the foundation for the microelectronics revolution and, consequently, the development of modern computers.

Space spin-offs are not limited to high technology. They extend to applications in medicine, energy, food, textiles, agriculture and many other areas. The economic returns that spin-offs have generated are very difficult to measure, because of how broadly they extend, the difficulty in defining what constitutes a spin-off (NASA, for example, specifies that commercialization as a result of direct Agency involvement is required, effectively excluding thousands of applications), and the fact that the impact of an application may not be evident until several decades after it is retired. Table 1[9,10,11] lists a few examples of spin-offs and their origins.

Table 1: From Space to Earth – Spin-offs

Space Programme Technology and Commercial Spin-offs	
Product	**Origin**
Tumour tomography	NASA scanner for testing
Battery-powered surgical instruments	Apollo programme
Non-reflective coating on personal computer screens	Gemini spacecraft window coating
Emergency blankets (survival/anti-shock)	Satellite thermal insulation
Mammogram screening, plant photon-counting technology	Space telescope instruments
Skin cancer detection	ROSAT X-ray detection
Dental orthodontic spring	Space shape memory alloys
Early detection of cancerous cells	Microwave spectroscopy
Carbon composite car brakes	Solid rocket engine nozzles
Car assembly robots	Space robotics
Flameproof textiles, railway scheduling, fuel tank insulation	Various Ariane rocket components, including software
Lightweight car frames, computer game controllers, fuel cell vehicles, coatings for clearer plastics, heart assist pump, non-skid road paint	Various Space Shuttle components
Fresh water systems	International Space Station technology
Corrosion-free coating for statues	Launch pad protective coating
Flexible ski boots, light allergy protection, fire-fighter suits, golf shoes with inner liner	Various space suit designs
Healthy snacks	Space food

Space Matters Down Here on Earth

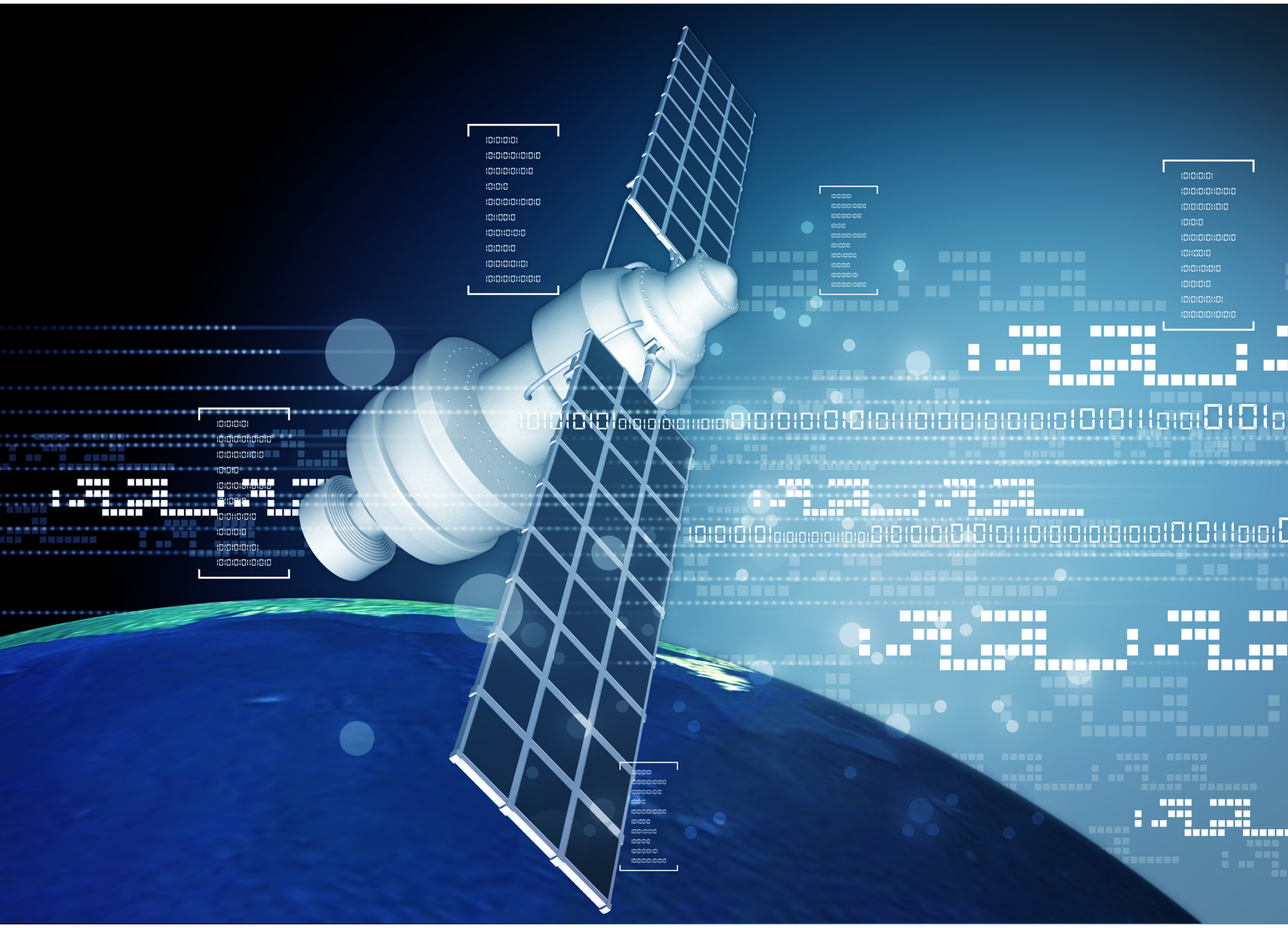
Every dollar spent on space is spent down on Earth. The design, research, development and manufacture of space assets employ hundreds of thousands of people, pumping billions of dollars into the world economy. However, the impact of space is far more pervasive than what can be detected from its economic footprint. While the space sector accounts for 1% Gross World Product (GWP), the true value of its contribution to the global economy is much larger due to the multiplier effect and the stimulus to growth that it generates.[12]

Space assets support critical infrastructure around the world and have lowered costs and increased efficiencies, resulting in benefits for millions of consumers. Satellites help save lives through weather and disaster prediction and disaster relief. Investment in space programmes has resulted in new technologies in areas such as healthcare that have improved the quality of life around the globe.

Space assets are becoming more and more critical to enabling sustainable, long-term development and narrowing the digital divide, thus helping to make the world a better place for all of humanity.

Space matters – and everyone has a stake in ensuring that it remains safe, sustainable and secure so that our children can continue to reap its benefits.

Book Contents



Chapter Snapshots

1 Communications Satellites and the Future Telecoms Ecosystem

The Problem

That information and communication technologies are indispensable for economic, social and cultural development is well recognized. However, the digital divide is a serious global problem, since in a good number of countries telephone penetration (teledensity) is very low. In today's society, free and open communication is expected by and for everyone, anytime and anywhere. Governments the world over are eager to make sure users can access as much high quality content as possible, at all times, no matter where they are, and at the lowest possible cost. All predictions indicate that the most popular form of traffic will be bandwidth-hungry video transmission. Unfortunately, while high-speed broadband networks exist in many cities, users still suffer from delays and a suboptimal experience due to congestion in the Internet backbone. This situation will only worsen as the appetite for content increases without the parallel roll-out of next-generation high-speed broadband.

The Space-based Solution

The ubiquitous nature of satellites – out of view from earth, high in outer space, but in view of wide regions of the globe – makes them unique beacons for robust communications. Along with WiFi solutions, they can use this natural strength to carry video content as close as possible to network edges for further distribution to the end user via terrestrial means, whether fixed or mobile. So they help to relieve congestion in the Internet backbone and enable delivery of high quality, media rich content to a maximum number of people over the largest possible area. In addition, satellites can connect people to broadband Internet no matter where they live, ensuring inclusive growth as the world moves forward in the Digital Era. Communication satellites are excellent instruments for bridging the digital divide and for spreading democracy and freedom around the globe.

Sample Applications

1. Connectivity on all devices thanks to satellite
2. Broadband coverage with O3b's "Fibre in the Sky"
3. A scheme to enable satellite TV reception in remote areas of India
4. The unintended consequences of regulation: Spectrum sharing and loss of service
5. 4K TV thanks to satellites
6. Bringing rural communities online in Italy

2 Using Space Technology to Improve Education in Remote, Rural and Infrastructure-challenged Regions: Africa, India and Beyond

The Problem

Many citizens in remote, rural and sparsely populated areas, especially in developing countries, face a digital divide that creates inequities between those who do and do not have access to educational resources. The ensuing lack of skills results in enormous income disparities and poverty.

The Space-based Solution

Cost-effective satellite enabled distance-learning programmes that function independently of ground-based infrastructure ensure connectivity across physical boundaries and thus help bridge the gap between the "haves" and the "have-nots".

Sample Applications

1. EDUSAT – Education in India
2. The African Virtual University
3. Satellite operators step up for South Africa
4. Brazil
5. Worldreader.org – Creating a literate world
6. China – Using TV for education

3 Space Technology and Human Health

The Problem

The ability to innovate on healthcare technology and delivery is a constant human need, especially in the quest to provide equitable care to people across the globe.

The Space-based Solution

Telemedicine enabled by space satellites and geographic information systems (GIS), scientific research and technology spin-offs enable new ways to improve human health on Earth.

Sample Applications

1. A global telemedicine and teaching network
2. The World Health Organization's GIS enabled "HealthMapper"
3. A NASA space station ultrasound spin-off for use in developing countries

4 Precision Agriculture and Food Security

The Problem

Food security concerns such as global population growth, limited production resources and global climate dynamics have engendered a need to produce more with less.

The Space-based Solution

By providing navigation, communication and data acquisition (remote sensing) capabilities, space-based technologies enable "smart farming" and the adoption of new and innovative practices on a global level.

Sample Applications

1. Automated guidance of agricultural vehicles helping farmers to save on agricultural inputs, extending the time of operation and reducing fatigue
2. Remote tracking of farm machinery enabling the optimization of operation logistics in an intensive production environment
3. Remote sensing imagery allowing spoon-feeding agricultural crops according to local needs and facilities irrigation

5 Using Space Technologies to Protect Human Rights on Earth

The Problem

Human rights abuses are often difficult to track, dangerous to investigate and, when reported, full of conflicting and unverifiable data. These constraints make it challenging to decide if, how and when the international community should intervene and prosecute violators of human rights.

The Space-based Solution

Human rights and humanitarian organizations can combine "eyes in the sky" – remote sensing tools, such as high-resolution satellite imagery – with geographic information systems (GIS) and eyewitness reports from the ground to raise public awareness, support international monitoring, and assist key actors in deterring and responding to human rights violations.

Sample Applications

1. Documenting deliberate village burnings, indiscriminate bombardment of civilians and mass graves in Sudan
2. Observing political prison camps in North Korea
3. Evaluating the human and environmental impact of unsustainable oil in the Niger Delta
4. Tracking terrorists, militia groups and other armed actors who poach elephants and rhinos in Africa as a means to fund mass atrocities

6 Climate Change and Space

The Problem

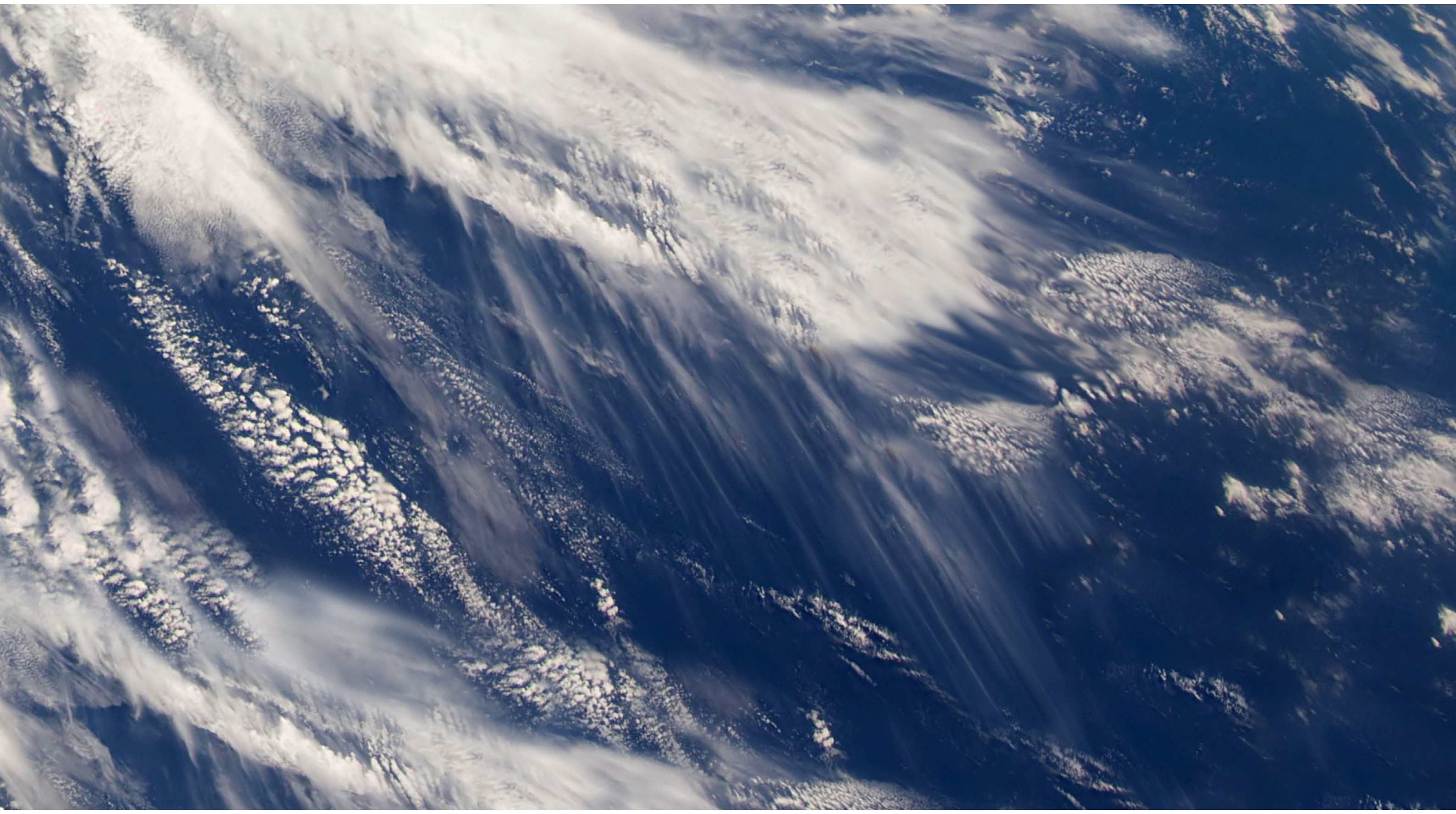
Climate change is one of the biggest concerns facing humanity; its consequences affect fresh water resources, global food production, sea levels and human security.

The Space-based Solution

Satellites provide researchers and policy-makers with vital information about the Earth's climate system, enabling the monitoring, prediction, modelling and implementation of mitigation and adaptation measures.

Sample Applications

1. ESA Climate Change Initiative's (CCI) satellite-derived long-term climate records
2. Copernicus Climate Change Service, which supports adaptation and mitigation
3. Monte Rosa Glacier, Italy, monitoring melting glaciers



7 Space Assets for Arctic Governance

The Problem

In the Arctic, climate change, rapid development and globalization have created the need for new approaches to conservation, resource management and governance.

The Space-based Solution

Remote-sensing and communication satellites can be used to develop Arctic infrastructure, ensure the sustainable management of the Arctic environment, generate science and improve awareness and knowledge, and ease geopolitical tensions.

Sample Applications

1. Space assets for measuring sea ice thickness over time
2. Satellites for providing communication services to remote Arctic populations
3. Improved mapping to help settle natural resource disputes

8 The Sustainable Management of Forests, Fisheries and Water

The Problem

The long-term sustainability of forests, fisheries and water resources is in danger. Many of Earth's most critical natural resources – particularly forests, fisheries and water – suffer from misappropriation, mismanagement and unsustainable use.

The Space-based Solution

Space-based technologies allow for improved observation, tracking and management of resource abundance, depletion and interventions.

Sample Applications

1. Using degraded land for sustainable palm oil in Indonesia
2. The monitoring and enforcement of fisheries in New Zealand
3. Water resource management and prospecting in Morocco

9 Using Space Technologies to Help Disaster Management

The Problem

Governments the world over are responding to an ever-increasing number of humanitarian crises, often as a result of natural disasters but also in conflict-stricken areas. These crises have a devastating impact on human society and, when they strike, their global, large-scale and complex nature limits the capacities of human resources and ground-based infrastructures.

The Space-based Solution

Satellite services and applications, whether for Earth observation, communications or navigation, provide support to disaster management teams and victims at all phases of both disaster preparedness and post-disaster response and play an important role in ensuring a coherent response in times of emergency.

Sample Applications

1. Philippines: Bringing the country back online after a monster typhoon
2. Syria: Humanitarian aid in times of conflict
3. Canada: Mapping Manitoba Wetlands with space images
4. Mexico: Landslides causing havoc after a storm

10 Nuclear Security and Satellites

The Problem

As the world's nuclear capabilities grow – along with their use for non-peaceful purposes – it is becoming increasingly essential for the international community to have the capacity to monitor the development, movement and weaponization of nuclear materials.

The Space-based Solution

Earth observation and communications satellites provide a non-intrusive means to both observe and verify nuclear activities on the ground.

Sample Applications

1. Canada's Bruce Nuclear Power Plant and a possible Fissile Materials Cut-off Treaty (FMCT)

11 Building Capacity to Prepare for Catastrophic Risks from Space

The Problem

Catastrophic risks from space are low-likelihood but high-impact events. Extreme space weather, for example, could harm satellites, disrupt pipelines and telecommunication networks, and collapse electric grids. Large objects impacting Earth could cause even greater regional or global damage.

The Space-based Solution

Space systems could improve knowledge about space weather, provide early warning and assist with preparation, and could even potentially be developed to defend against large objects that threaten Earth.

Sample Applications

1. Space weather: The 1859 Carrington Event and 1989 Solar Flare
2. Objects hitting Earth: The 1908 Tunguska and 2013 Chelyabinsk events

12 The Challenge of the Long-term Sustainability of Space Activities

The Problem

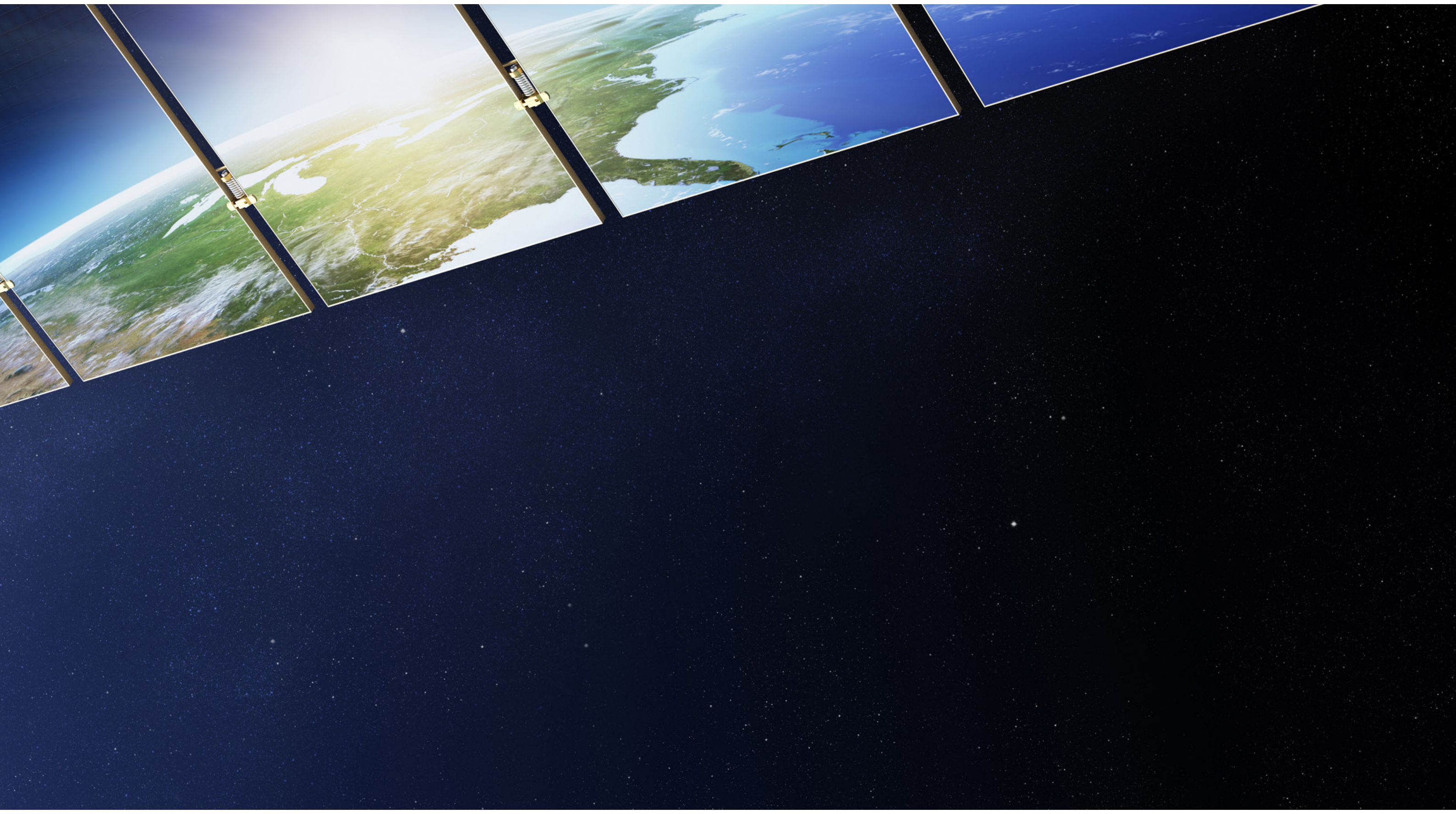
As increasing numbers of state and non-state actors operate in space, challenges of radio frequency interference, collisions as a result of orbital space debris and the increasing number of satellites in space, as well as unstable strategic military use all pose serious threats to the long-term sustainability of Earth orbits.

The Space-based Solution

No one solution can address these challenges. Instead, a basket of initiatives, including improving space situational awareness, developing norms of responsible behaviour, reducing the creation of new orbital debris while removing some of the largest existing debris objects, and increasing transparency and confidence-building measures, offers the best chance of ensuring the long-term sustainable use of Earth orbit.

Sample Applications

1. Mitigation of risks in space: The Space Data Association
2. Interference with satellite signals and resulting loss of service
3. Space debris: China's deliberate destruction of a weather satellite
4. Strategic instability: The deliberate destruction of USA 193



Conclusion

Space is no more than 80 miles away from every person on Earth. As political scientist Daniel Deudney once observed, that is far closer than most people are to their own national capitals, and yet the great beyond has slowly drifted out of much of the world's consciousness in the four decades since mankind's first giant leap during the height of the Cold War.[13]

Even so, space capabilities greatly improve many aspects of people's lives, and we humans are becoming more reliant on them every day. Currently, approximately 1,000 active satellites provide a whole host of benefits that improve the world in many ways. Examples include efficient global navigation and transportation, essential communication services and daily weather forecasts.

The space industry also helps to address some of the major challenges facing humanity as it offers capabilities that other technologies and solutions are less suited to provide. This results in tangible enhancements to citizens and organizations, including the safeguarding of basic human rights, the sustainable management of the environment and natural resources, improved health, education, safety and security, prevention from and response to catastrophic risks, and overall enhanced economic prosperity.

Despite the benefits, a number of very real threats put the industry at risk. These include spectrum congestion and interference that can interrupt or prevent the services provided, damage to satellites from increasing amounts of space debris, and the growing number of actors in space due to the commoditization of space hardware, all of which endanger the strategic and political stability of space.

However, the principal danger to space capabilities is humans' underestimation of their positive impact and overarching importance. Without them, the innumerable public, private and civil applications that mankind has grown to depend on and has become accustomed to would cease to exist. To prevent this turn of events, the space industry must continue to forge strategic partnerships with governments, business and civil society to develop collaborative solutions to tackle the major challenges worldwide, and further enhance everyone's daily lives. In return, the space community relies on the commitment of these groups to raise awareness of the space environment's importance to policy-makers and the wider public.

Space capabilities are critical infrastructure for the world that must be understood as such. Clearly, space matters, right here on Earth.

Endnotes

[1] "The Space Report 2013: The Authoritative Guide to Global Space Activity". Space Foundation, http://www.spacefoundation.org/sites/default/files/downloads/The_Space_Report_2013_overview.pdf, April 2013.

[2] "Government Space Markets, World Prospects to 2017", http://www.euroconsult-ec.com.

[3] Claire, J. and Razi, G. The Space Economy at a Glance: 2007. Paris: OECD International Futures Programme, Organisation for Economic Co-operation and Development, 2007.

[4] Ionin, A. "Russia's Space Program in 2006: Some Progress but No Clear Direction". In Moscow Defense Brief, Centre for Analysis of Strategies and Technologies, 2006.

[5] Khorram, S. Remote Sensing Satellites. New York: Springer Press, 2012.

[6] "GNSS Market Report, Issue 3". Prague: The European GNSS Agency, http://www.gsa.europa.eu/node/8748/download/067a7554f8815b9ee528feb737db42c7, October 2013.

[7] Pelton, Joseph N. Satellite Communications. New York: Springer Press, 2012.

[8] Ibid.

[9] Peeters, W. Space Economics and Geopolitics. International Space University Executive Space MBA lecture notes, 2001.

[10] "Down to Earth: How Space Technology Improves Our Lives". European Space Agency, http://esamultimedia.esa.int/multimedia/publications/BR-280/pageflip.html, 2009.

[11] NASA Spin-off website. NASA, http://spinoff.nasa.gov/, 2013.

[12] Gurtuna, O. Fundamentals of Space Business and Economics. New York: Springer Press, 2013.

[13] Outlook on the Global Agenda 2014. Geneva: World Economic Forum, p. 60, http://www3.weforum.org/docs/WEF_GAC_GlobalAgendaOutlook_2014.pdf.

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