CRISIS RESPONSE JOURNAL

SPACE EDITION IN ASSOCIATION WITH SERCO

WWW.CRISIS-RESPONSE.COM

PROTECTION | PREVENTION | PREPAREDNESS | RESPONSE | RESILIENCE | RECOVERY

SPACE: COOL FOR CATS

AND BENEFICIAL FOR HUMANITY

A special edition produced by Serco and Crisis Response Journal

Special edition: The human space race

Welcome to this special Space Race edition of Crisis Response Journal, put together with Serco, the international specialist in the delivery of essential public services across defence, transport, justice, immigration, healthcare and other citizen services in the UK & Europe, North America, Asia Pacific and the Middle East.

Beginning in the late 1950s, the Space Race between the USSR and the US left a lasting legacy of Earth communications, weather and other earth observation satellites, and also sparked increased spending on education, research and development.

The consequences of this legacy are an almost ubiquitous use by today's society of a myriad of ever increasing essential needs and applications that are almost totally reliant upon space-based assets, infrastructure and capabilities.

Transfer technology derived from space is behind the scenes in our daily lives, affecting how we travel, communicate, generate power from the sun, drink, eat and sleep.

What we wear, developments in health and medicine, safety and food supplies have all been transformed by space research.

In fact, in many of our routine daily activities, it is likely that some critical element of both the physical and informational supply chains either directly, or in part, involves space.

The human race is indeed now the Space Race.

Serco has a sizeable interest in space. This is both in the literal sense, where its work with organisations, such as the European Space Agency or UK Ministry of Defence, involves it directly in the assets and technology of ground and space-based infrastructure.

But it is also involved in a societal sense, where information derived from space, and the essential services that rely upon it – and thereby affect the lives, safety, security and wellbeing of millions of people every day – are supported by many essential services that Serco provides for governments across the globe.

But the effects of space-derived information on societal well-being goes beyond the delivery of essential services. Information from space provides a vital element of intelligence for decision-makers and this data is integrated, used and governed as part of the wider information and intelligence mix to enable better informed decisions.

When used in a joined-up way, this information can achieve a combined effect with the myriad of other data information available. It is a multiplier of the collective effort, and helps support protection from harm, and the promotion of wellbeing of hundreds of millions of people across the world every day.

The complex evolution of space systems, along with humanity's reliance upon them, means that we must be aware of evolving vulnerabilities and maintain constant vigilance on their overall resilience. And this resilience is examined in detail in our second article within this special edition.

Together with the Crisis Response Journal, with whom we have a shared interest in the safety, security and resilience of society, we have put together this broad insight into some of those areas of space-derived information that affect the well-being of every human on the planet.

It's been enjoyable putting this together with the CRJ team and we hope that you'll find it informative and as enjoyable as we have.

■ **Laurence Marzell, Serco**

Cover image: Vadim Sadovski | 123rf

EDITOR IN CHIEF
Emily Hough
emily@crisis-response.com

SALES & MARKETING DIRECTOR
Kirsty McKinlay-Stewart
kirsty@crisis-response.com

GLOBAL OPERATIONS DIRECTOR
David Stewart
david@crisis-response.com

CHIEF SCIENTIFIC EDITOR
Ian Portelli, BCDM, PhD
ian@crisis-response.com

SUBSCRIPTIONS
Crisis Response Journal is published quarterly; it is available by subscription in hard copy, digital and online
subs@crisis-response.com

BACK ISSUES
Existing subscribers: £25 (US$45; €36) per hard copy issue (free with online access);
Non subscribers: £40 (US$72; €58) per issue
backissues@crisis-response.com

Published by Crisis Management Ltd
Sondes Place Farm, Westcott Road, Dorking
RH4 3EB, United Kingdom
Tel: +44(0) 7825 012 5160; mail@crisis-response.com
www.crisis-response.com

Printed in England by Henry Stone Ltd

www.crisis-response.com
join the *CRJ* LinkedIn group
follow us on twitter @editorialcrj

Crisis Response Journal is the international publication for all disciplines involved in preparing, mitigating or responding to natural or human-caused emergencies, spanning subjects such as leadership, command and research, through to resilience, counter-terrorism, cyber-safety and medical crises. The journal is available by subscription only and there is a range of subscription options, including hard copy, digital, institutional and corporate. All subscribers can access our digital content archive
www.crisis-response.com

Space: At the heart of human existence

Laurence Marzell says that the legacy of the superpower Space Race of the 1950s is still paying dividends today, as we rely on information for essential services that keep society, communities and citizens safe, secure and resilient

Every man, woman and child is now part of the Space Race. If you Tweet, travel, transact, talk, text or taste, there will be some element of this that is brought to you from space.

The Space Race between the US and USSR for technological dominance of space in the late 1950s has left a legacy of earth communications, weather and other earth observation satellites, which has sparked increased spending on education and research. Today's society depends on many essential services for health and well-being, many of which are themselves reliant – in full or in part – upon information from space.

In this article, I focus on one of the most critical aspects of information from space – its use in decision-making and the governance of information surrounding it. This insight is derived from Serco's experience in delivering essential services for governments worldwide, together with examples of how Serco, with others in academia, industry and the public sector, are innovating across these areas.

In order to be made even more useful to decision-makers, information derived from space needs to be combined with a wider information mix from a myriad of different sources. This will drive better informed decisions to minimise the impact of shocks that affect us all: whether from natural, man-made or malicious causes.

Trusted data

Data, whether visual, textual, or auditory is just 'data' until a human is aware of it, trusts it to inform a decision, and feels confident to act upon it. Space data is no different.

Decision-makers face a continuous need for faster, more trusted and better informed data, particularly where it is interpreted and turned into usable intelligence and can be counted in terms of lives lost or saved. Here, a number of critical factors converge and compound themselves.

In today's complex and interconnected world, planning and preparation for – and response to – the threats and risks society faces are conducted by different organisations that need to work together towards a shared goal. Interoperability between those different organisations is essential. This is challenging on many levels, not least in terms of governance.

The need for better informed decision-making can be manifested in different ways. As an example, at the strategic level, sufficient and reliable intelligence might be required on Boko Haram activity in Nigeria to warrant external intervention. At a lower but no less critical level, it may be needed in peacekeeping, humanitarian relief and disaster response operations, or by law enforcement agencies to act against serious organised crime or terrorism. Whichever the need and whatever the data and information source, it can be a real challenge to turn such disparate data into usable intelligence in a unified way so as to allow multiple different organisations to act coherently and achieve their shared aims and objectives.

Organisations view the world in which they exist and must operate in very different ways. These opposing views are driven by many factors, most notably risk, but also history, culture, capability, economics, legislation and leadership.

These factors shape how organisations conduct their business, including the governance and policies, training, budgets, processes, systems and technology that underpin their operations.

An organisation's view of the world, relative to the other organisations with which it must collaborate, is neither right nor wrong, good or bad; it's just different. But these differences, especially in governance and policy terms, are where the gaps exist. The gaps from these differences create risks, where failures can – and often do – occur. Following a major incident, dependencies and interdependencies inherent within today's complex and interconnected world, could lead to consequences and cascade effects far beyond the original cause.

In the aftermath of well-documented major incidents where decision-making and interoperability between different organisations has been judged to be less than effective, it has been recognised and often cited that failures in governance have frequently been the underlying cause.

The information of interoperability, intelligence assessments and decisions this drives, needs to flow across organisational, operational or jurisdictional boundaries, both internally within organisations (or nations) as well as externally.

These differences are further compounded by a set of issues that pose significant challenges for decision-makers.

The ability to collect data far exceeds current analysis techniques and the 4Vs of data (volume, velocity, variety and validation) requiring analysis are increasing logarithmically – the problem is getting bigger. Thus more efficient (process) or faster (technology) approaches are required in data analytics for professional and expert individuals and analysts who sift through data, looking for themes and insight, and create summaries.

The pervasiveness of 24-hour news and social media means politicians need an increasing confidence that intelligence has the highest probability of being correct and remaining time-stamped (ie valid) to enable an appropriate response. This is regardless of either civil or military use, domain context or whether the open source intelligence is derived from space or from other sources, such as social media.

During the cold war, 90 per cent of the data used for intelligence-based decision-making was obtained from military or other agencies and 10 per cent from open sources. Now, the figure is 90 per cent from open sources, with the remaining ten per cent deriving from military or other agencies.

Big data and the benefits of big data analytics are much discussed and promoted but are little understood, let alone properly integrated into decision-making contexts.

When acted upon, information and data from space-derived sources, like the other information and data that forms part of the wider information and intelligence mix, needs some form of feedback to the end user that their actions are appropriate.

The collection and dissemination of data is only half the challenge; the capacity and capability of a human being faced with rapidly increasing data volumes and complexity will be the key determining factor of successful data usage and assimilation.

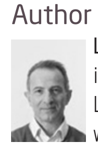
Serco delivers essential public services in defence, transport, justice, immigration, healthcare and other citizen services across the UK, Europe, North America, Asia Pacific and the Middle East. It has a sizeable interest in space through its work with the European Space Agency (ESA) and UK Ministry of Defence (MoD), being directly involved in the assets and technology of ground and spaced-based infrastructure. Serco's interest is also societal, as evidenced by the extent to which space data is relied upon by millions of people who depend upon its services daily for their safety, security and well-being.

To support and further this interest, Serco takes part in collaborative initiatives that enable improved outcomes through better-informed decision-making. Using its knowledge and expertise as an end user and operator of essential services, it aims to help inform and shape innovation and improvements in information governance to drive a more joined up, unified and integrated approach, which can make a real difference to people's lives.

In these initiatives, Serco seeks to inform how a joined-up decision-making and information governance framework, aligned to outcomes, can help bring multiple

The Royal Australian Navy's Bridge Training Facility (BTF) features two full-mission simulators and four part-mission simulators, each offering up to 180-degree view field, which are used for navigation, command and control training. Serco instructors are embedded within the BTF to train Navy officers in controlling and manoeuvring ships in simulated warfighting environments. Scenarios are played out over two 17-week courses, held annually. The instructors are also supported by Serco's Operational Support Officer who provides 'Train the Trainer' and supplementation on other courses, ranging from initial navigation to advanced navigation

Author



LAURENCE MARZELL
is Combined Effect
Lead for Serco
www.serco.com

A Serco engineer at the UK MoD's Skynet satellite communications ground facility

different organisations together in a shared understanding of risks and outcomes. This facilitates their collective roles, responsibilities, capabilities and capacities to support and multiply the combined effect of their collective effort. It also helps to visualise the dependencies and interdependencies that exist across, between and within organisational boundaries, through a shared understanding of the threats and risks that are faced. This provides an overall view of where improvements to interoperability might occur, across the areas of people, process, technology and governance.

Serco has three European Horizon 2020 innovation projects where, together with partners across Europe, it seeks to apply innovation to decision-making in a practical and meaningful way.

Moses Project

Moses is an information platform for water procurement and management agencies in areas such as reclamation and irrigation. It is designed to help manage and reduce the risk of droughts and their impact, save water, improve services to farmers and reduce financial and energy costs, by facilitating the planning of irrigation water resources.

Water procurement and management agencies and consortia play an essential role in preventing and managing flood risk, helping reduce their social and economic impact, and Moses provides valuable products and services in this respect. Seasonal probabilistic forecasting and numerical weather prediction are vital in this regard and here, Moses can be considered a form of 'climate service' as it provides seasonal forecasting of water requirements to agricultural water providers, helping them to plan water procurement and allocation before the start of irrigation season, so that they can mitigate the risk of water shortages and improve water procurement efficiency. It also provides detailed in-season monitoring of crop water requirements, allowing updates, fine tuning and adjustment of allocation plans and water resource management to districts and farmers.

To achieve this, Moses combines information, data and technological resources, including: Earth observation data; probabilistic seasonal forecasting and numerical weather prediction; crop water requirement and irrigation modelling; and an online GIS decision support system. Users access the system depending on their expertise and needs and the system's services range from river basin to sub-district.

Four demonstration areas in Italy, Spain, Romania and Morocco have been set up to consider different water procurement and distribution scenarios, to collect data and user needs, interface with existing local services and develop the service further. Moses will work with these demonstration areas to collect information on crop calendars and irrigation practices, as well as on data availability with reference to the system.

Auggmed Project

In July 2015, IEEE, the world's largest technical professional organisation dedicated to advancing technology for the benefit of humanity, published an article on the use of virtual reality (VR) for the training of first responders. Drawing upon a study from the University of Virginia, it stated that firefighters, bomb disposal officers, and others responding to emergencies need hands-on training that is safe and inexpensive and that VR simulators could be the answer to this. Technological advances in this field are likely to reduce training costs, while simulated scenarios can provide a safe environment for first responders and security personnel to practise in.

In early 2015, as part of the EU Horizon 2020 programme, Auggmed received €5.5 million to develop its serious game platform for first responder training. Two years into the three year project, Auggmed is well on the way to showing how virtual and mixed reality training of first responders can be applied at a practical level.

The 2015 study by the University of Virginia highlighted that designing a VR system requires an enormous amount of detail and data, which makes it difficult to translate into simple user interfaces. The researchers also stated that the virtual systems seen today may look like programs that can be applied to training, but they are created by visual artists and hence do not provide the specific details first responders need.

As a result, Auggmed links the Unity games engine used in many commercial games, with the Exodus state-of-the-art evacuation and circulation simulation software tool, which models crowd behaviour, based on the best available data. This novel approach and integration increase the perceived realism and hence the system's immersiveness. The system allows end users to assume a variety of roles within the simulation and to interact with the simulated crowd. In addition, Auggmed implements mathematical models describing the effects of fire hazards and explosions on people and infrastructure. In particular, numerous statistics based on physical and medical research describe the potential effects on the human body, as well as the structural elements of buildings.

The Auggmed prototype will allow trainers to set learning objectives for individual and/or teams of trainees (from a single or multiple organisations), to define scenarios, monitor progress of the training session, alter scenario parameters during the session, provide real time feedback and assess trainees' performance.

This multimodal virtual reality and mixed reality platform will be able to be used anywhere, via various devices from smartphones and tablets to high-end PCs with multiple monitors and head mounted displays. It can automatically generate bespoke scenarios, which are accessible by a trainee at a time and place of their choosing. This allows training to take place as often as required, in scenarios involving arbitrary population sizes, with users interacting with the crowd and trainers able to initiate a remote, unplanned session to test the readiness levels of team members.

Auggmed offers first responders a doctrine-neutral environment for decision-making. It helps to exercise emotional management, along with critical and analytical thinking against the relevant doctrine, training needs and outcomes that their organisations seek and wish to evaluate performance against. Auggmed is designed to facilitate both single and multi-player training, so a key capability is the ability to test doctrinal concepts set against the improvements identified through a unified decision-making and information governance framework.

Unity Project

Serco leads the design and implementation of a framework of governance for community policing (CP) in the Unity Horizon 2020, project together with multiple European partners in law enforcement and academia. CP across the UK, Europe and further afield, is the bedrock for keeping society and its communities and citizens safe, secure and resilient.

Unity is building a community policing architecture framework (CPAF) to underpin a shared view of risks, threats, vulnerabilities and hazards across the entire community. It supports a governance structure and framework that enables multiagency organisations to work collectively and more effectively together, addressing the challenges of better informed decision-making within the complex community system.

The CPAF will simplify and manage the inherent complexity of a multi-stakeholder and dynamic environment. It is a 'single source of truth' that drives agile and iterative testing, along with the governing rules and principles of CP across multiple different partners.

Unity has been specifically designed to understand the structural issues and challenges of decision-making from the citizen and community up, using CP scenarios developed from comprehensive research by Unity partners across EU member states; then tested in pilots in Croatia, Estonia, Bavaria, Belgium, Finland, Macedonia, Bulgaria and the UK.

Unity's combined effect approach for mapping and understanding the roles and relationships of multiple stakeholders in complex environments, highlights the dependencies and interdependencies across four key capability areas that embrace multi-agency working, namely governance, people, process and technology.

The combined effect focuses on the collective effort and capability that stakeholders can achieve across essential shared and common aspects, such as risk, governance and outcomes.

Unity delivers usable information, helping multiagency organisations with better informed decision-making to improve their community policing outcomes.

Summary

Society increasingly depends on space data to fulfil everything from getting to work, to getting the shopping. It is estimated that 100 per cent of civil air transport and shipping relies upon location and timing from space. Road, rail, utilities and hospitals could not continue to function without precise timing from space, and automated building security systems would be compromised without space-derived information.

Space-based open source imagery is increasingly being used to ratify decision-making, both in military contexts as well as in civilian law enforcement areas, as it provides information that might not previously have been possible to ratify. There are potential benefits for a more unified and seamless governance of the integration, application and exploitation of space-based data into the wider information and intelligence mix in support of a spectrum of civilian law enforcement and emergency applications. These include humanitarian, disaster and crisis response, along with prevention, detection, disruption and response to serious and organised crime or terrorism. Here, greater exploitation of space-based data could improve operational efficiency and effectiveness, as well as providing economic benefits alongside better informed decision-making.

Faster, more accurate and trustworthy intelligence to support decision-making could improve the quality of decisions made by politicians at the strategic level, as well as decision-makers on the ground. This would improve the quality of life of society, its citizens and communities in times of danger and need. And such an outcome is wholly aligned to Serco's vision where it would like to encourage dialogue with others across the spectrum of decision-making.

MOSES

Project Co-ordinator: Marco Mazzolena, ESRI Italia; Technical Development Management: Vittorio Marletto ARPAE Emilia Romagna; Demo Area Co-ordination: Gabriella Scarpino Serco Belgium ; Scientific Supervision: Prof. Massimo Menenti DUT, The Netherlands
www.moses-project.eu

AUGGMED

Exploitation, Communication & Dissemination Lead: Laurence Marzell, Serco
www.auggmed-project.eu

UNITY

Community Policing Architecture Framework Lead: Laurence Marzell, Serco
www.unity-project.eu

Critical space infrastructure and space security

In the winning entry to the RUSI Resilience Prize in 2015, **DR LIVIU MURESAN** and **ALEXANDRU GEORGESCU** look at how the complex evolution of space systems create benefits and vulnerabilities

Resilience is the ability of a complex system, such as a human society, to withstand the harmful impact of unexpected negative events while mitigating their damage and enabling the rapid resumption of a normal state of functioning. It is a deeply complex concept, related to others such as robustness, flexibility and rapidity. Some authors have tried to make sense of the concept by connecting it to the three underlying capacities a complex system can exhibit – an absorptive, restorative and adaptive capacity.

Others try to identify principles of resilience as a sort of roadmap towards developing this abstract quality in an indirect fashion. Stig Johnsen (2010) defined seven such principles of resilience, easily understood in the context of resilience of complex, technical and human, systems-of-systems: graceful decline; management of margins; common mental modes; redundancy; flexibility; complexity reduction; and de-emphasising couplings between system components.

What is certain from the increasing emphasis on resilience and existing research is that resilience is deeply circumstantial and arises or falls from the characteristics of the system in question. Pre-globalised, low technology economies have a certain resilience profile that is completely different to that of an advanced, globalised economy. An autarkic nation such as North Korea certainly seemed less affected by the 2008 global financial crises than prosperous and open nations such as the US, but one finds it hard to envy the North Koreans their poverty.

To describe resilience in 2050, it is crucial to describe the societies in that era, especially with respect to their underlying economic, social and political functioning. Whether or not it comes to pass, the trend seems to be that all societies want to increase their prosperity. The underlying framework of such development is an evolving system of infrastructures, both technical and organisational, concentrated and diffused, ranging from pipelines and power plants to agricultural and water systems, as well as health, education and finance systems.

These infrastructures work in concert, meaning that they are interdependent and their proper functioning as a whole is required for a multilaterally developed system. This makes them critical to the well-being of a system-of-systems such as a human society.

The complexity of the interconnections and the degree of dependence on these systems engender an intractable problem – to grow, one needs to develop critical infrastructure. The more you have, the more exposed you are to certain threats and vulnerabilities, both known and unknown, which can have dire repercussions through cascading failures within the systems.

Take the example of a notional city, the undisputed engine of growth in the current development model, featuring a concentration of critical infrastructures, where summer consumption overwhelms the electricity grid and results in the interruption of supply for a certain period of time. This leads to cascading disruptions in many infrastructure systems – public transport (underground), food and water systems (storage, distribution, waste management), financial, educational, health systems and, last but not least, in administrative capacity, which is considered a critical infrastructure under the European Union Programme for Critical Infrastructure Protection (EPCIP). Public order would be affected, especially if the situation continues, as rioting and looting occur and the security services are unable to properly co-ordinate an effective response or simply attend to all of the hotspots.

It is in relation to these critical infrastructures (CI) that the concept of resilience has become a fixture in security and policy discussions. Economists used to speak of capital accumulation in general terms as a basis for economic development, but we can now also speak of infrastructure accumulation as a precondition for development, with criticality as a side effect. The paradox is that a society will only be as prosperous and as safe as its critical infrastructures allow, thus setting both lower and upper bounds to prosperity by encumbering it with the weight of the security perspective.

It is understood that the relentless drive towards greater efficiency and economic growth often outstrips the capacity of the security apparatus (both formal and emergent) to keep up with emerging threats and vulnerabilities.

Methods of inventory management such as 'just in time', which minimise acquisitions and storage costs by relying on clockwork delivery schedules within global chains of production, illustrate this penumbra of incompatibility between growth/efficiency and resilience. Security standards may be developed and imposed, or voluntarily adopted by private actors for the sake of minimising upheavals, but the truth remains that resilience is, to a certain extent, anti-efficient if society ends up being critically dependent on the gains made with each new degree of efficiency.

Johan Swaenpoel | 123rf

RUSI Resilience Essay prize winners

CRJ teamed up with the Royal United Services Institute (RUSI) to judge a Crisis Response Journal category in the Resilience Essay Prize. The overall topic was 'Resilience 2015: A Blueprint for the Future' and the CRJ category encouraged new thought and leadership on international resilience.

CRJ published the overall winning essay by Dr Liviu Mureșan and Alexandru Georgescu of the EURISC Foundation in Bucharest Romania in edition 11:3 (March 2016). This essay looks at critical space infrastructure and space security within a resilience context in the next few decades.

We also published the winner of the CRJ category, written by Ryan Meeks of the Frazer-Nash Consultancy, who explores how to build a resilient critical national infrastructure in the age of the Internet of Things, homing in on the 'ripple effect' of insider threat attacks on connected systems. This article is available in our archive for subscribers on our website. Contact us for more details on how to subscribe.

You can find the runner-up entry, by Philip Wood, MBE, MSc, Head of School, Management and Professional Studies at Buckinghamshire New University in the UK on our website (www.crisis-response.com).

The Essay Prize winners were announced at the RUSI Resilience Conference in October 2015.

www.rusi.org

Limiting growth itself is unlikely as a conscious policy, since it is deeply impolitic and would be regarded as being regressive and on the wrong side of history. To borrow a phrase from American political conservatism, it is akin to: "Standing athwart history, yelling 'stop'."

New methods have to be developed to maintain resilience, because achieving it is nigh impossible in an ever-evolving infrastructure landscape, where regional criticality is replaced by global criticality, whose handling outstrips the jurisdiction, resources and, ultimately, vision of most security actors.

It is in this gap that the capabilities of space systems have come to play an important role. Future historians might debate which role came first, that of adjuvant to resilience issues or detractor from it, but the rapid rise in the use of space capabilities is a telling indicator of their significant advantages.

Space systems have become a key enabler of a wide range of applications for billions of beneficiaries, if not consumers. Satellites and satellite constellations provide multiple services, such as communications, Earth Observation and remote sensing, navigation, positioning and timing. These capabilities supplement or complement those of critical terrestrial infrastructures, and enhance them. Just to give an example, global transport systems today are increasingly dependent on Global Navigation Satellite Systems (GNSS). Even the banking system depends on the atomic clocks of GNSS for time-stamping innumerable transactions, while electricity grids depend on them for synchronising increasingly complex systems of energy producers and consumers.

Crucially, from the perspective of resilience, space systems have become an upper layer of command, control and co-ordination capabilities that are spreading – owing to technical prowess, efficiency and cost effectiveness – to many critical infrastructure systems. This engenders a critical dependency on these capabilities, which leads to the conclusion that space systems are themselves becoming critical infrastructures and therefore not just part of a solution, but part of the problem.

The EU and national authorities (overwhelmingly those of the most developed states, but also the strongest of the emerging world), which are the main drivers of Critical Infrastructure Protection (CIP) efforts and research, are increasingly coming around to this development and are scrambling to update their mental modes, organisations and documents of reference to reflect this new variable.

It is true that, for instance, weather monitoring has become an extraordinary tool in the hands of emergency and crisis situation management, not just for everyday economic activities (agriculture, transport, etc).

Space systems have become a boon for localised disaster management, but this proficiency has led to a dependency that spawns new threats and vulnerabilities, given the challenging and complex security environment in which space systems have to operate.

The year 2050 is liable to offer more of the same, featuring not some resolution to the problem of ensuring resilience, but an eternal tightrope balancing act to handle existing security issues by deploying capabilities which, in turn, may create new issues, all the while hoping that the security calculus will turn out to have been in the black. We can get a glimpse of the future today since, as science fiction author William Gibson quipped: "The future is already here, it is just not evenly distributed."

The largest economies, at least in per capita terms, are also the most technologically advanced and therefore the most endowed with critical infrastructures. These countries are also the progenitors and heaviest users of space capabilities. The contrast is not only with poor, underdeveloped nations, which have themselves become marginal space services consumers under the aegis of international development projects that seek to bypass elements of local critical infrastructure development. Developments such as skipping the construction of landlines for communication and going straight to mobile communications, or using remote sensing for sustainable water use were unavailable to Western nations during their incremental development on the technological and economic frontier.

The contrast is also with the past, which shows a clear progression towards greater use of space systems. The militaries of developed nations, especially that of the US, have been at the forefront of developing space capabilities, which were then adapted for civilian use. Among them is the first global positioning and navigation system (GPS), which is still a project of the American Department of Defence (DoD). Consequently, military thinking in space security issues is still among the most advanced, as critical dependency issues manifested earlier and have been under scrutiny for a longer period of time.

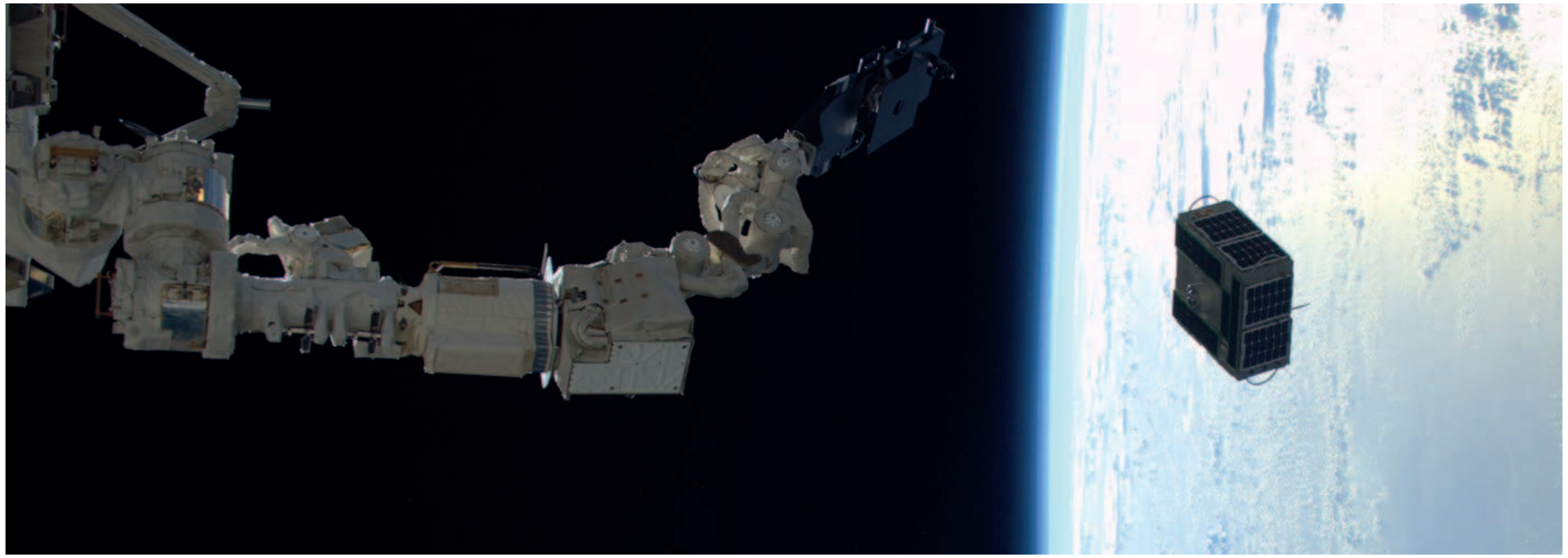
Cloud of electrons

The US owns 152 of the known existing 270 military satellites, as well as countless other civilian satellites with implicit dual use capabilities (ie most of them). To highlight the degree to which the military is a trailblazer for space dependencies, a single Global Hawk drone that flies over the Middle East consumes more transmission bandwidth than was consumed during the entire Gulf War in 1991, and 90 per cent of the US military traffic passes through civilian satellites, many with a private owner, and not through systems constructed to be resilient to various means of interrupting their functioning. Furthermore, 68 per cent of American ammunition used in Iraq was guided through satellites, while only 10 per cent was guided in the same manner during the Gulf War. Already, American strategists have stopped talking about the fog of war and have started talking about the 'cloud of electrons' and about the fact that space systems are an Achilles heel for the US.

Military exercises like Army After Next, Navy Global, Air Force Global Engagement, Space Game 2, Schriever 1 and 2 and Deadsats, confirmed the fact that: "Politicians, economists and company chiefs ignored the fact that space losses can affect national, economic and social security, not just in the United States, but also in the entire world." American experts concluded that even major military powers could be: "Taken hostage by the unknown elements of a new type of war." Another military exercise, Pacific Vision, demonstrated the vulnerability of commercial communications satellites on which they depend. Referring to China's 2007 anti-satellite weaponry (ASAT) test, General Harnel from the Space and Missile Systems Centre declared that: 'Losing asymmetric advantage in space will regress the American war machine from the informational age to the industrial age," in favour of the adversary.

The writing has therefore been on the wall quite a long time, for nearly a generation now. The use of space systems is on a natural growth path and the trends will be maintained in 2050. Space capabilities will be a crucial enhancer for the growth and development of already advanced nations, and a key component for the catch-up growth of the less developed nations. Space capabilities will also be a crucial component of the resilience capacity of nations, while undermining it at other levels. Dependencies will abound, not just of the first order, but also at secondary and tertiary levels, where cascading disruptions will challenge even countries that thought themselves beneath reliance on space systems.

Crucially, one does not have to be a participant in a new space race to be dependent on space systems, as many smaller developing or developed nations are fully-fledged users of space services without ever having launched a satellite. Such situations underline the complexity of resilience in the age of the space systems, since they lead to subtle political risks (or limitations on security efforts) resulting from a dependence on infrastructures that are not under their jurisdiction, being owned by foreign companies under the sovereignty of other states and subject to other laws.



Tim Peake of ESA captured this photo from the International Space Station, during the deployment of two satellites, which form the Low Earth Orbiting Navigation Experiment for Spacecraft Testing Autonomous Rendezvous and Docking (Lonestar) investigation

ESA | NASA

The pseudo-military nature of GPS is a very good illustration of how a critical dependency has been formed at global levels on an infrastructure under an authority that can arbitrarily terminate or degrade its service to certain categories of users, such as civilians of allied states.

We can posit not just a trend in the growth of the use (and dependency on) space systems, but an acceleration based on factors that seem likely to materialise today, reducing the barriers of access to space:

- A projected lowering of the launch costs, given greater competition in the field;
- A lowering of new asset cost, through technological development, economies of scale, new design philosophies (modular satellites, nanosatellite swarms);
- A lowering of costs such as insurance and financing, through a better understanding of the security environment and the gradual build-up of a better framework of commercial exploitation of space under more predictable conditions (global governance, international organisations dedicated to administering the global space commons, international legislation and an adaptation of existing commercial law and customs to space, including for potential liability); and
- New business models for access to space, including the ESA's Copernicus Programme, which features an open-source data model for the observations of the Sentinel satellites.

Of course, this simply complicates the issue of whether the trend in the space services sector is towards greater resilience with regards to critical dependencies on space systems through an expansion of the capacity of the sector, or whether there will be such a rise in consumption that it will erode any possible capacity reserves for the provision of space services (possibly even goods, in the future), thereby reducing resilience.

We mentioned the trade-off that is taking place through the advancement of the space services sector, where increased and more efficient economic and security governance activities also register a corresponding increase in exposure to new types of risks, vulnerabilities and threats, resulting from these systems. The security profile of critical space infrastructure is markedly different from that of the average National CI.

For one, space itself is a highly international environment, a sort of global commons, where security actors are hamstrung by jurisdictional issues, cross-dependencies that render geographical and territorial borders irrelevant and gaps in the international framework for the governance of such environments, which is apparent in the growing issue and threat of space debris.

Owing to barriers of access to space and the types of services being provided, the number of active space systems is very small relative to the extraordinary number of consumers and other beneficiaries. The Union of Concerned Scientists maintains a database of known satellites by ownership, orbit, type of activity and other metrics.

Because of weight limitations and the need to provide specialised services, most satellites are built for specific tasks. Therefore, the degree of interoperability and substitution that can cushion the effects of a disruption in services is very small. Constellations exist to provide global coverage and the amount of built-in redundancy is very small, since every new asset is leveraged for maximum economic gain. The trend has been for private companies to assume greater importance in critical space infrastructures, just as in terrestrial CI, which obviously produces tension between the profit motive and the requirements of security and prudence. Consequently, the systems featuring the most redundancy are the government-sponsored constellations, such as the various GNSS systems, which feature back-up satellites to prevent degradation of service in case of asset loss. The Galileo GNSS features an interesting degree of interoperability with the American GPS system and the Russian Glonass, while all major players also use ground-based amplification stations to improve the accuracy of positioning.

Coupled with the high risk of spontaneous malfunction in a very hostile environment saturated with radiation and other hazards, in which repairs are most often impractical and replacement takes a long time, this means that space systems are, at the same time, critical assets, critically undermanned and critically threatened. Other specific vulnerabilities are related to the exposure of space systems to human interference, as their orbital paths are well known and predictable, as well as clustered in the most profitable orbital bands; in addition, their paths may take them above areas inhabited by hostile elements.

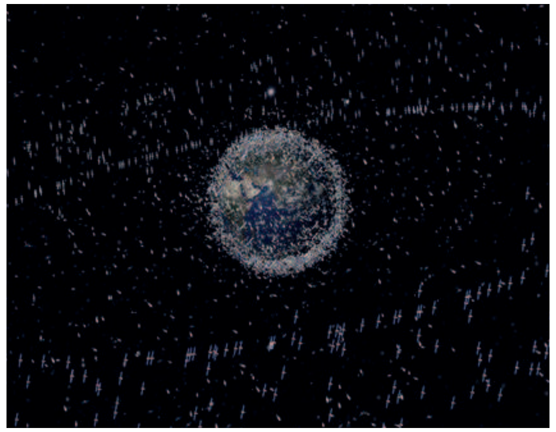
According to a Rand Corporation report, space systems make enticing targets, especially for non-state actors that are insensitive to the logic of mutual deterrence that inhibits nation states from attacking space assets on which there might even be a mutual dependence. Their disruption or destruction appears to be a crime without casualties, but with extraordinary economic costs beyond the simple cost of replacement and can be more attractive in a political sense.

Furthermore, the means to attack space systems are increasingly at the disposal of non-state actors or rogue states and are also very diverse, ranging from kinetic weaponry to cyberattacks and from signal jamming to laser blinding. Some of these attacks can have highly specific outcomes – stealing or faking data, temporarily blinding a satellite to inhibit surveillance, inhibiting communications – and are not just the province of terrorists and rogue states, but also of potential organised criminal elements.

Certain means of attack are especially attractive, since they provide an extraordinary difference between the cost of attacks (including failures) and the value of a successful strike. Having a laptop with an Internet connection and an operator with specific skills is a very low threshold for implementing an attack that debilitates world markets or robs decision-makers of certain capabilities at critical junctures (during an emergency situation, for instance). Jamming, especially at ground stations, is also a low-cost and low sophistication approach, with increasing availability of off-the-shelf equipment for such operations.

Space systems also face two specific threats – space debris and space weather, the latter of which can also impact terrestrial CI, especially in energy and communications.

Most human activity is concentrated in a thin layer of orbital space surrounding the Earth, where decades of launches, accidents, collisions and carelessness have produced hundreds of thousands of objects larger than a centimetre hurtling through space at eight km/s. Orbital



The number of objects in Earth's orbit has increased on average by 200 per year since the first satellite launch in 1957 by the then USSR. The debris objects above are an artist's impression based on actual density data, shown at an exaggerated size visible at the scale shown

European Space Agency

space is one of the least regenerative environments known to man, and there have been fears, such as the Kessler Syndrome proposition, of debris density becoming so high that one final collision produces a cascade effect, turning Low Earth Orbit into a dangerous minefield.

In February 2009 an American commercial satellite collided with a Russian military one at the speed of 11.7 km/s. The number of traceable debris generated by the incident was over 2,000, with thousands more too small to trace. This was the first random collision between satellites at hyper speeds, although there had been other incidents in the past. The Russian satellite was a 950kg, nuclear-powered military satellite called Kosmos-225, launched in 1993 and deactivated in 1995. The American one weighed 560kg, had been active since 1997, and was link number 33 in the Iridium Corporation communication network of 66 units. Iridium said it received 400 weekly close proximity warnings, issued when an Iridium satellite is within five km of another satellite, and Iridium 33 was scheduled to bypass the Russian relic by only 560 metres.

ASAT weaponry tests have also been a source of space debris and, in case of conflict, could provide the trigger for a Kessler Syndrome situation. For instance, the ASAT test run by China on the 750kg FengYun-1C at 865km altitude on January 11, 2007 increased the number of monitored orbit debris by 12 per cent – North American Aerospace Defence Command (NORAD) has detected over 2,000 new objects the size of golf balls or larger, with the likelihood of 100,000 smaller objects that are equally dangerous.

Unlike extreme Earth weather, which disproportionately affects the populations of poor countries, space weather impacts rich countries above all others, since they are the biggest consumers of space services and they derive the greatest economic added value from employing them in the economy. Space weather is primarily made up of the high-speed ejections of plasma from the Sun, which experiences periodic solar flares, but also incorporates other sources of radiation and charged particles. There has never been a truly destructive solar flare event, because only recently have we become vulnerable to them. We have the example of the Carrington Event, which in 1859, led to auroras manifesting at the Equator, measurement devices becoming erratic and world telegraph networks being heavily damaged.

Despite never being severely tested, our vulnerability has grown with each passing year to the extent we can safely say that it has become an existential threat for developed societies. One of the largest modern instances, on September 13–14, 1989, led to a loss of contact with numerous space assets for over a week and left six million inhabitants of the Canadian province of Québec without electricity for several hours, and many planes grounded or rerouted.

Solar weather can also lead to disruptions of services and significant damage at terrestrial level. In 2003, during the 'Halloween storm', which was another peak of solar activity, alongside power disruptions on the ground, orbital activity was seriously affected – 59 per cent of scientific missions were interrupted, astronauts had to take refuge in specially shielded areas of the ISS, and a number of satellites were lost.

Should a modern Carrington Event occur, the US National Academy of Sciences (NAS) estimated damages at two trillion dollars in the first year for the US alone, and recovery times between four and ten years, not counting damage to electricity grids in Europe, lost economic opportunity and so on.

Other key terrestrial infrastructure can also be disrupted, mostly as a result of the loss of electricity and communications. Future events could exploit weak links in infrastructure systems to inflict even greater damage, with the NAS estimating that, owing to vulnerable and ageing transformer stations, over 130 million consumers in the US alone would be deprived of electricity for more than a few hours. Space systems also play a vital role in researching these phenomena and warning against them.

Peak vulnerability

Extrapolating these trends to 2050, mindful of potential technological breakthroughs, allows a picture of how space systems will both add to and detract from societal resilience. By then, every country developed to at least the economic and technological level of the early 21st century will have registered a critical dependence on space systems, especially for emerging countries which have leapfrogged over technological stages to directly utilise space services. Countries will be richer and safer from a host of potential disasters and disruptions through ubiquitous surveillance, information gathering and co-ordination at accessible price levels through space systems.

However, the world will be at the peak of its vulnerability to space debris and space weather, while a cautious détente between spacefaring nations is maintained by cross-cutting issues of dependence, if not on the same systems, then at least on the health and safety of the 'global commons in space'.

This will also be a time of opportunity for violent non-state actors looking to disrupt world affairs, though it is arguable that the systems will have become more resilient in themselves, regardless of the financial and market impact of temporary disruptions, based on the psychological effects of uncertainty which are beyond the security decision-makers' ability to affect.

The main barrier to resilience is that of creating a global governance framework with powers to regulate space activities in a way that increases resilience. The current framework, based on voluntary associations between space agencies and other actors, as well as voluntary adoption of technical standards without power and authority to penalise actors who deviate from these norms, is woefully lacking. The UN's Committee on the Peaceful Uses of Outer Space has been developing such technical standards, but with little power of enforcement. Different treaties are supported by a mosaic of nations in various stages of adoption, while other treaties lack the support of the most powerful space players who are holding out for a framework that is to their specific advantage. Organisations such as the International Telecommunications Union, which regulates and assigns communication frequency bands to avoid 'frequency fratricide' between nearby satellites (which is also a potential ASAT weapon) shows that the orbital commons can be adequately regulated.

Going forward, an international governance framework conducive to such resilience would:

- Regulate the production and disposal of new space debris;
- Regulate oversaturated orbital bands, preferably through market mechanisms;
- Incentivise the development and application of methods for clearing up orbital debris;
- Promote the adoption of resilient satellite design, taking advantage of new technologies and lower costs of launch (for shielding) to increase lifespan and decrease failures, as well as ensure the highest possible extent of interoperability;
- Develop a multi-stakeholder model of governance, focused especially on co-opting private actors (who will own the bulk of future satellites) in a security conscious process, while addressing their needs for an environment more conducive to commercial exploitation;
- Another target should be non-spacefaring nations, who must nevertheless take space security into account for their CIP strategies and activities. This is especially important since, in an interconnected world, one weak link also undermines the other countries through cascading disruption, even though they may have thought themselves adequately protected from threats;
- A comprehensive effort at disseminating knowledge, best practices and critical technologies and standards, while co-opting as many members as possible into arrangement such as early warning networks and rapid intervention initiatives; and
- A focus on terrestrial infrastructure, hardening it against threats such as space weather phenomena, a process which involves not only investment and upgrades on the ground, but the use of space systems for adequately early warning and research.

In the end, space systems are a critical tool in negotiating the often-conflicted relationship between economic development and security concerns. Their use enables us to achieve a greater measure of resilience towards certain kinds of disasters than ever before, but at the cost of exposure to new threats. By 2050, we will have not only integrated them into existing and future CIP frameworks at national, European and global levels, but will have also gone through a number of challenges that will have strengthened resilience.

Experts studying the low intensity space weather phenomena that have produced damage, have remarked on how they represented stress tests of existing infrastructure and wake-up calls for the need to address these issues. As a result, the various examples of space system disruption and destruction have been a positive incentive for security conscious development. This relates to the concept of anti-fragility, where repeated low-level crises strengthen a system against a major threat that could have otherwise destroyed the system entirely. This philosophy is now being applied to CIP and to space security issues.

By 2050, the effects of past incidents will have already spawned a more resilient society, but it will have become obvious that the road to resilience extends much further into the future, as long as societies continue to develop and avoid stagnation.

Resilience, in this respect, is less of a destination for security experts and decision-makers, and more of a constant journey.

The findings presented in this article are based on a research project – 'Space Systems as Critical Infrastructure' – led by the Romanian Space Agency, with the Military Equipment and Technologies Research Agency of the Romanian Ministry of Defence and the Eurisc Foundation. The work was supported by a grant of the Romanian National Authority for Science Research, A full list of references is available upon request

Authors

DR LIVIU MURESAN is a noted Romanian security expert. After serving as Leader of the Majority in the Romanian Parliament in 1990 – 1991, he occupied a number of advisory positions, including as Senior Advisor to the Prime Minister, the Government and the Minister of Interior, and served as Deputy Director of the National Defence College. He leads the Eurisc Foundation, a private research institute

ALEXANDRU GEORGESCU is a Research Fellow with the Eurisc Foundation, mainly studying geopolitics, international security issues and critical infrastructure protection. He is pursuing a PhD in Risk Engineering for Critical Infrastructure Systems

AUGGMED

THE SERIOUS GAME PLATFORM

MULTI-AGENT COUNTER TERRORIST TRAINING IN MIXED REALITY ENVIRONMENTS WITH AUTOMATED SERIOUS GAME SCENARIO GENERATOR

AUGGMED is developing a serious game platform for single and team based training of end-users with different levels of expertise from different organisations responding to terrorist and organised crime threats.

The platform will automatically generate non-linear scenarios tailored to suit the needs of individual trainees with learning outcomes that support improved emotional management, analytical thinking, problem solving and decision making skills.

The game scenarios will include advanced simulations of operational environments, agents, tele-communications and threats through virtual reality (VR) and mixed reality (MR) environments with multimodal interfaces.

Facebook.com/AUGGMED @AUGGMED laurence.marzell@serco.com www.auggmed-project.eu

Partners

BMT Group "Where will our knowledge take you?"
WyFi
FGC Ferrocarrils de la Generalitat de Catalunya
ΟΛΠ PIRAEUS PORT AUTHORITY S.A.
UNIVERSITY OF BIRMINGHAM
GeoMobile
serco
emergències mèdiques
CENTRIC Centre of Excellence in Terrorism, Resilience, Intelligence and Organised Crime Research
Sheffield Hallam University
ISRATEAM
the UNIVERSITY of GREENWICH
POLITÉCNICA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653590