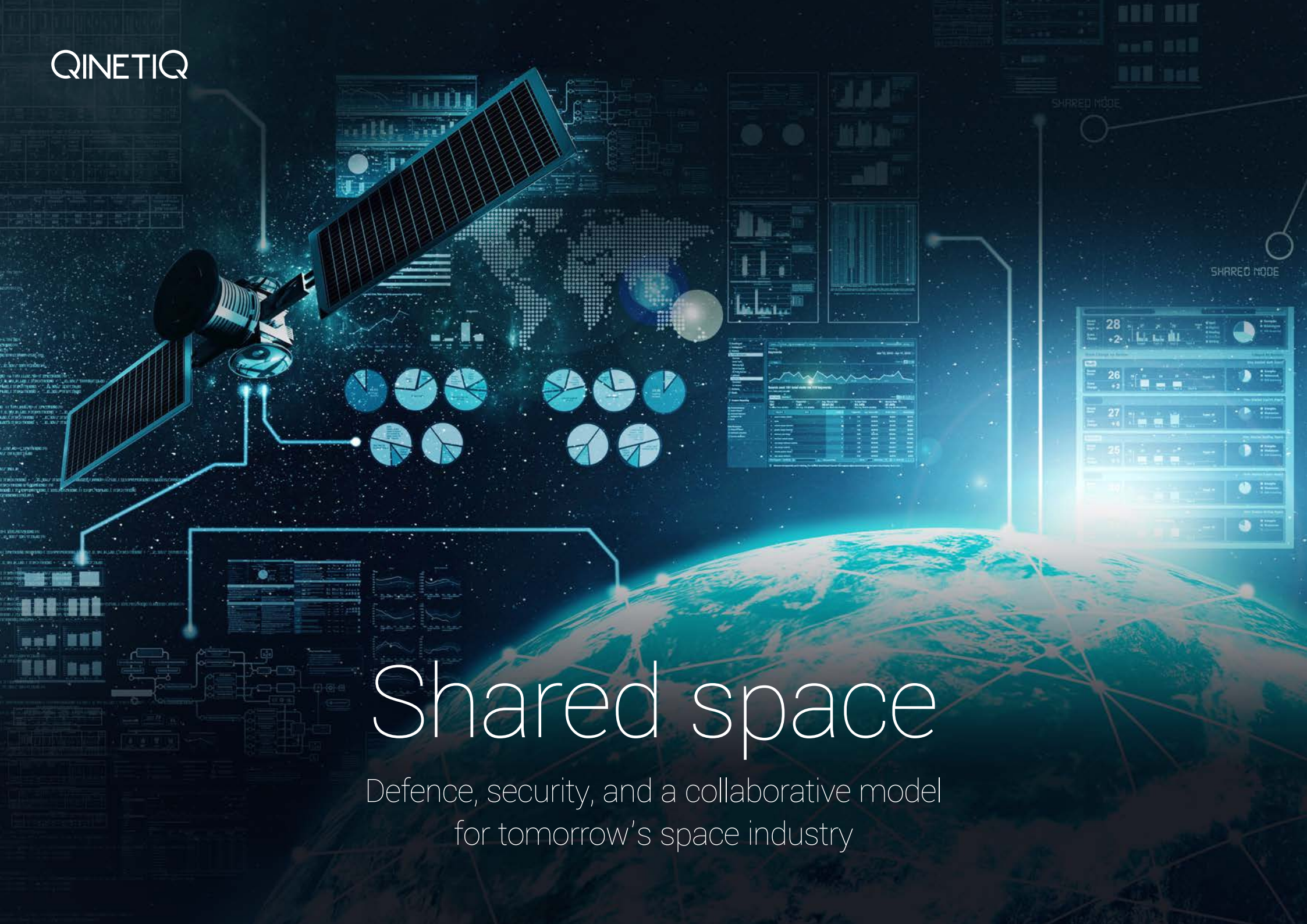


QINETIQ

Shared space

Defence, security, and a collaborative model
for tomorrow's space industry





Introduction

The legendary composer John Cage once said: "There is no such thing as an empty space or an empty time." This is truer now than it has ever been.

Space is becoming a busy place. The Space Race has given way to the NewSpace race - characterised by the introduction of a raft of new, nimble and entrepreneurial actors, and a decline in the longstanding cost and technology barriers to the capabilities that enable successful, secure operations in space.

As a result, the next few decades will be very different.

The real sea change is the commercial sector's increasing involvement. Between 1958 and 2009, almost all of the investment in space was by major public institutions, like National Aeronautics and Space Administration (NASA) and European Space Agency (ESA). But in the past decade, private investment has risen sharply to reach 15% of the total spend. In 2020, despite the pandemic, such spending hit a record \$8.9 billion and annual global revenue from space-based services exceeded \$300 billion for the first time. More than two thirds of this went to commercial organisations.

That does not mean that governments are becoming redundant in space. Far from it. Public institutions and governments still have a critical role to play, but their days of primacy in the space sector are over. In the past two decades, start-up space companies have shown they can compete with (and in some cases upstage) larger sovereign bodies. They have entered the domain, propelling a move away from the traditional model of centralised, government-directed human activity in space. In doing so, they have driven the sector forward more vigorously than if it were left to governments alone. But the next step isn't about one facet or another, because many of today's biggest challenges to progress in space - space debris, anti-satellite weapons, or the scientific challenges of deep space exploration - affect governments and businesses equally. These are everyone's issues, so they need to be tackled cohesively. As a result, neither commercial nor public organisations can succeed in isolation. Both are essential to progress.

Commercial and private mindsets bring innovative, agile approaches to space's challenges. They are not bound by the same bureaucracy as public offices. They are more comfortable taking risks and they are traditionally better at rapidly harnessing innovation. Public bodies and governments may move more slowly, but they do so with greater heft. They have the financial clout to underpin expensive commercial endeavours that shareholders simply wouldn't (or couldn't) fund, they have decades of sector experience to help accelerate new ideas, and they provide a neutral environment where traditional competitors can advance together.

In today's space sector, what connects public and private organisations are the safety and security needs of such a strategically-important domain. For example, hypersonic space debris does not discriminate between public and commercial assets. What is unsafe for a government defence mission is equally unsafe for a private company's satellite constellation. As more nations and organisations come to rely upon space, and as it becomes more congested, contested and competitive, all participants will require new ways to protect what matters most. It is here that successful partnerships can (and are) being built, and it is why meeting defence and security challenges is now a central tenet for the collaborations that will make NewSpace relationships effective.

Building these relationships requires an understanding of the foundations that will allow them to prosper. This report proposes four areas that make that possible:

- **Knowledge-sharing** - combining legacy and new knowledge to best effect
- **Financing** - using public and private sector investment tools to pay for space success
- **Innovation** - sharing innovation resources to achieve rapid progress safely
- **New partnership models** - new ways of working together to extract the most value from the widest range of relevant participants, quickly and fairly

Working with specialists across QinetiQ, and external experts from the wider space industry, the report explores each of these areas, identifying the role of each in successful relationships that achieve defence and security objectives through public/private collaboration. It concludes by offering a series of recommendations that can enhance space capabilities, both for those seeking to obtain a commercial advantage, and those seeking to use space-based assets to protect people on the ground.

Space transcends traditional boundaries, and so should our efforts. This report is designed to stimulate the thinking required to do so.

Jim Graham,

Managing Director, Space

Knowledge-sharing

In his book 'An Astronaut's Guide to Life on Earth', Chris Hadfield - one of the world's most experienced astronauts, highlights the importance of promoting colleagues' interests in space programmes: "It's easy to do once you understand you have a vested interest in everyone else's success".

That mindset is essential when it comes to sharing new and legacy knowledge, because both are critical. During the early years, reaching orbit was hard. Between 1957 and 1962, 32% of American and 30% of Soviet launches failed. Only nation-states could afford such risks, so they have learned the most from legacy failures. In the past two decades, start-up space companies have shown they can compete with (and in some cases upstage) larger sovereign governments. Their programmes offer a wealth of new innovation knowledge drawn from experience in other industries - but it is built on the earlier learnings from nation-led space programmes. Both pools of knowledge and experience add significant value when combined.

What hampers this mindset is that there is, and will continue to be, significant dichotomy in intention when comparing what private industry and government each want from space. Private companies recognise the congested future of space, so are increasingly turning to more ambitious, less competitive 'space-for-space' businesses - areas in which they may be able to make an outsize impact. Meanwhile, governments will inevitably continue to focus on 'space-for-Earth' activities that are in the public interest, such as satellite navigation and communications.

The upshot is that commercial players are largely failing to tap into what government can offer. That will be a limiting factor in both sides' future success. So, how can the public sector's decades of experience become a shared, mutually-beneficial resource? And what lessons can be learned from the gains of the small, agile commercial players who are making progress in NewSpace?

First, it requires both parties to identify clear areas of common ground where progress will be thwarted by a lack of knowledge-sharing. Defence and security is such an area, where combining that legacy and novel experience with innovative new ideas is vital, because space-based assets now have to do a lot more than before. Until recently, success was measured by the outcome of launch, the ability of assets to survive in space, and their ability to complete their objectives when beyond Earth's atmosphere. This is changing now that critical infrastructure is becoming more reliant on space resources, and adversaries are developing counter-space capabilities that could destroy, degrade or deny our most essential space-based assets. It is no longer good enough just to have a satellite that can survive launch and initial operations, it must now be defensible.

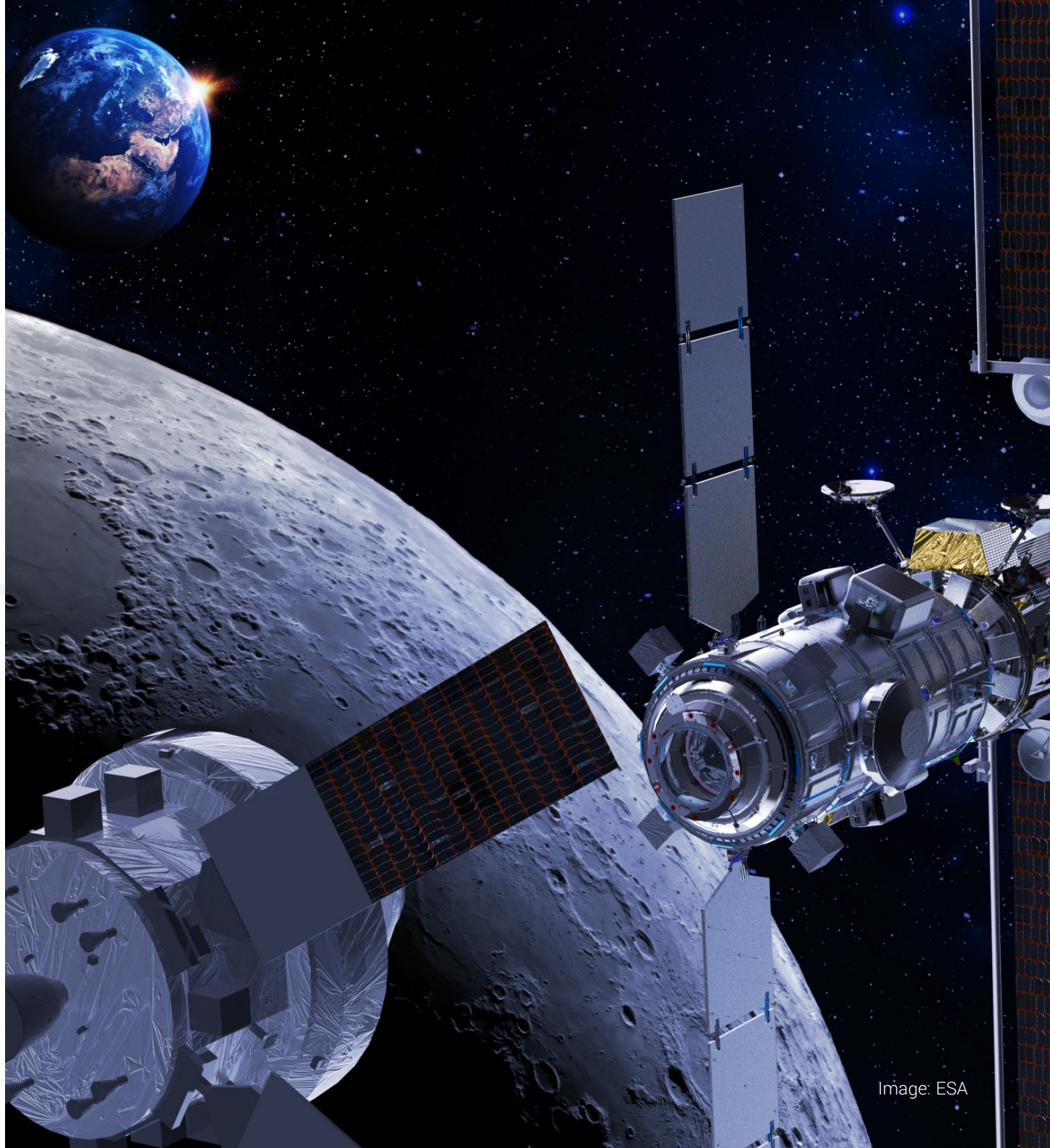
Secondly, shared training needs to be commonplace. Commercial businesses need to increase the amount of training they do, based on legacy knowledge from the public sector. The lessons learned from the high-cost government space programmes of the past should not be forgotten. New players need to formalise those learnings through collaborative training programmes designed in partnership with government departments and civil institutions, all based around clear outcomes that focus on what will deliver the most tangible improvements. For example, the UK government has set up a new virtual Space Sector Export Academy to provide training to small and medium-sized enterprise (SME) space businesses and increase international trade, investment skills and knowledge. The academy aims to work with government departments and local partners - using their existing knowledge of the space domain to reduce trade barriers and support international partnerships that generate commercial opportunities.

At the same time, government bodies must grow their understanding of the new and emerging technologies, systems and processes that are being readily harnessed in the private sphere.

If they are to be more than just a finance system for future space endeavours, public organisations should learn how to adopt the 'fail-fast, learn-fast' methods adopted by NewSpace players.

Finally, standards and regulation should become a key environment for the type of knowledge-sharing this report proposes. Governments need to apply their heritage in the sector to legislation, such as setting standards for safety and security in space. This requires significant understanding of the different needs from the various communities involved and will, inevitably, depend on governments. But it will also rely upon strong foundations of collaboration across public and private actors. A wealth of previous, present and future knowledge will need to be combined in order to define the correct institutional frameworks. Many administrations are developing their own space laws - not only long-established space-faring nations such as the US or Russia, but also countries with limited space activities - those who wish to attract new investments from abroad, or to support their own fledgling space industries. And, while excessive regulation will stifle industry, if developed collaboratively with commercial players, some government policies - such as those around reducing space debris - can help reduce the risks of operating in space for everyone in ways that would be difficult to coordinate independently.

Collaborative initiatives in space can flourish by recognising what each player's knowledge can offer to overarching progress in the domain. If public organisations continue to harness the innovation knowledge of private firms, it will increase their effectiveness whilst empowering NewSpace's commercial innovators. Likewise, smaller players should appreciate the resource pool spanning half a century that public organisations can offer. Going it alone will only impede progress to one extent or another.





Financing

Space has always been expensive. But now it's also big business. Space-enabled services have delivered enormous socio-economic value for decades, and this value continues to grow. The EU plans to spend €14.8 billion as part of the 2021-2027 EU Space Programme. And as part of the National Space Policy, the UK has a stated ambition is to grow the value of its space sector to £40 billion by 2030.

National growth ambitions, coupled with a continued fall in financial barriers to entry, means the marketplace is also increasingly diverse, as hundreds of start-ups rush in. As the market changes, the challenge of how to pay for that growth needs to be addressed. It is not a question of what to spend, but how to spend it wisely. The answer lies in the hybridisation of public and private sector investment models, where both parts of the process provide valuable input to generate mutual benefit. For that to work, several things are important.

The first is that private organisations need to undertake much of the innovation. Traditionally, space programmes were entirely government-run, incredibly expensive and largely classified. Governments still maintain vast budgets, but the ways they use them are beginning to change, outsourcing much of the innovation and servicing to the private sector. This needs to continue and governments need to keep stepping back, but without stepping down. By doing so, they can use their financial clout to provide direction - by acting as the first adopter, the early-stage venture capitalist, and the 'anchor tenant' of the space sector, allowing the private sector to progress far quicker than if it had to rely solely on private investment. The approach blends two very different obligations - governments look to protect the public interest and provide stability and direction, whilst entrepreneurs pursue new markets and spot the opportunities governments can't.

Both are important if society is to take advantage of all the opportunities space can offer.

Whilst the trend for public sector outsourcing should continue, the size and scope of programmes should change. One of the main lessons and recurring themes of the emerging space domain are the advantages that can be gained from disaggregating monolithic legacy programmes into more numerous, smaller and more affordable public-private partnerships (PPP), where the vision comes from the private sector, the work is underwritten by public funds, and the outcome offers collective benefits to all. Most governments have ample experience of carving up large programmes into smaller projects to be delivered by private firms. In space, the US government is by far the largest customer of satellite-related services today - and a leader in the PPP approach. Indeed, The National Aeronautics and Space Act, and the US National Space Policy both mandate that NASA work with industry to advance the commercial space sector. Long-term, sovereign governments wish to build their own native space industries, and, downstream, they wish industries to 'stand on their own two feet' - as that is where a sustainable industry is to be found. But, building space capability is more akin to 'planting seeds' than 'building foundations'. It's hard to begin without some initial government help.

ESA's TIA (Directorate of Telecommunications and Integrated Applications) with its ARTES 4.0 (Advanced Research in Telecommunications Systems) programme is an example of this. It supports innovation by enabling industry to develop products and services that benefit both parties. The International Space Station (ISS) is another example of governments enabling private sector - as is the Commercial Orbital Transportation Services (COTS) programme that supports it. Initiated by NASA in 2006, it encourages the private sector to develop spacecraft and rockets to take cargo to the ISS, in partnership with participating governments.

This 'co-investment' allows public and private organisations to share risk, and it allows the commercial entity to recoup its investment by eventually being able to do business. In theory, both parties win - and both get what they need. But increased interoperability between government and industry is essential to optimising these complex financing processes in large public-private space projects. Without it, expensive misunderstandings, such as scope creep or cost overruns, can result. This can be avoided by clearer briefs in the early stages and a mutual appreciation for shared and individual goals throughout the project lifecycle. Ultimately, a greater understanding from both contractors and governments can benefit everyone.

Innovation

'Innovation' has been something of a hollow buzzword for many years. But it provides focus and direction when led by an overarching mission; harnessing it effectively is essential in our pursuit of space. In this instance, all future space activity is under threat, and protecting space assets and the services they enable is a unifying goal across borders and boundaries. This provides a platform on which to enact greater collaboration. Faster progress towards these goals can be achieved through enhanced 'dual-use' technologies. The dual-use concept is gaining traction, and ultimately underpins the idea of collaborative innovation.

Dual-use: the double-edged sword

'Dual-use' broadly describes a capability that can serve both commercial and military purposes. It is not a new concept. An estimated 95% of space technology can be considered dual-use. Certain technologies, like low Earth orbit observation satellites (which, for example, can be used for tracking military targets as much as they can provide data for wine cultivation) are infusing national security considerations into a growing range of strategic technologies. Recent examples include US Department of Defense (DoD)-contracted rocket launches that set aside auxiliary storage slots for private micro-satellites. Dual-use is certainly not limited to Western nations, also being a tenet of China's military-civil fusion (MCF) doctrine.

The intrinsic complexity involved - where offensive systems could be disguised as defensive ones - has escalated this issue internationally. For example, in the US, dual-use technologies are subject to the same stringent export controls as weapons sales.

Even the computing power of some Apple components is subject to regulation, around concerns of manipulation for military use.

Though it is easy to focus on the geopolitical and strategic implications of such technologies, those very implications can (and should) drive collaborative innovation, and trigger a call to action around greater synergy. As the amount of dual-use technology increases, trade has become intertwined with national security issues and geopolitical risk.

Developing those technologies safely (and with appropriate security measures built-in) requires a combination of experience that cannot be found in public or private environments alone. Plus, at its very basics, dual-use has obvious benefits for both public and private sectors; it allows expensive, complex resources to generate revenue and serve commercial purposes, whilst also being able to meet military needs when required.

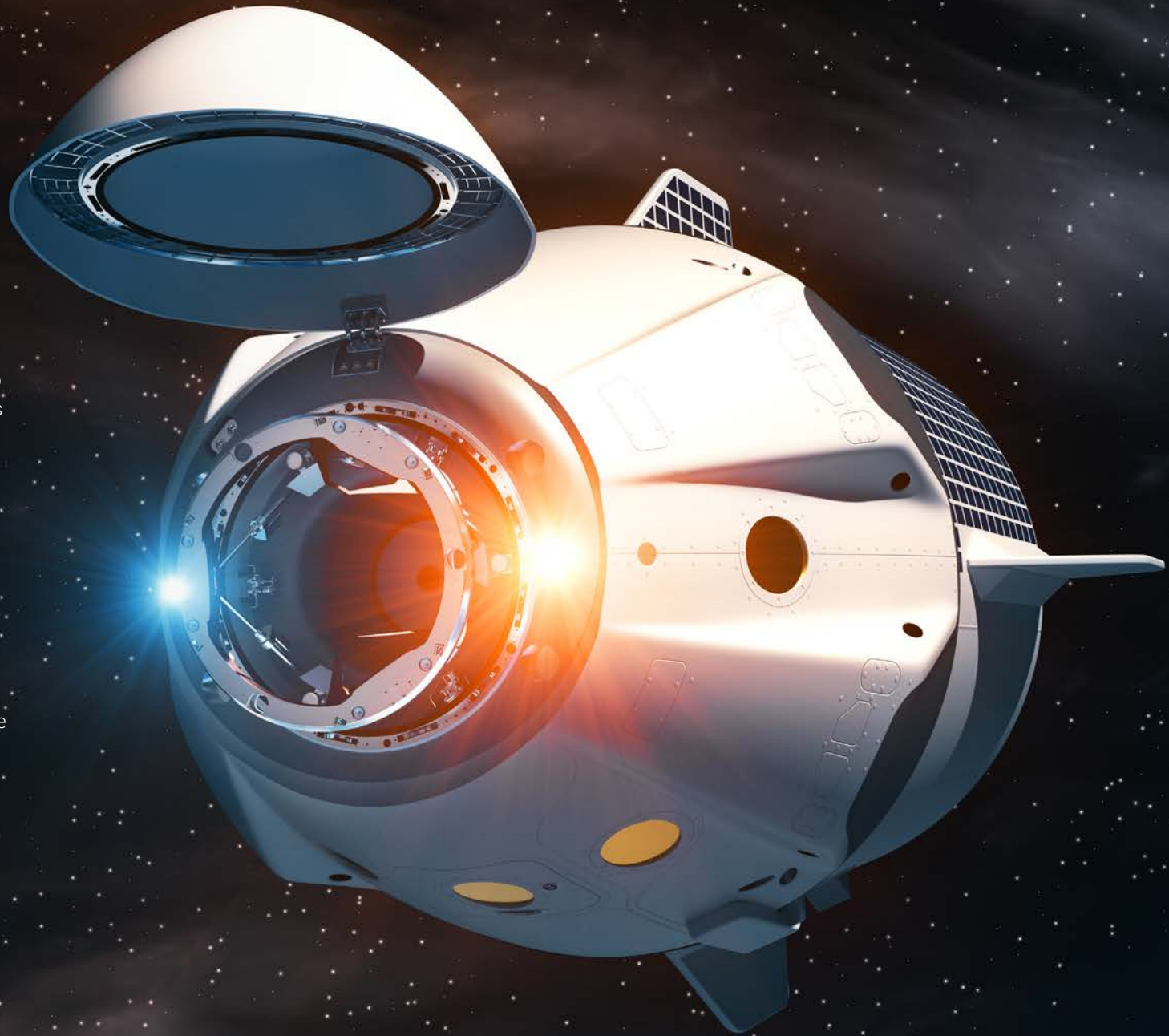


Opening the innovation space

If they haven't by now, public bodies must accept that private industry now leads much of the innovation space. As such, governments can almost certainly benefit from adopting private-style innovation practices in some areas, but ultimately should not attempt to entirely reproduce the outcomes of the private sector. Part of this is continuing to recognise the key role that public organisations can play as incubators to early phase innovation.

Legacy suppliers have repeatedly shown that they still have their place - however, diversifying the innovation landscape from a small number of large prime contractors, to an 'ecosystem' of diverse, smaller companies will offer extensive benefits to governmental buyers. But for this ecosystem to work, public organisations must give more opportunities to the private sector to innovate. Interoperability between various supplier's systems will be paramount. Governments should push for open, compatible standards and architectures, in order to avoid 'vendor lock' (a situation which places reliance upon a single supplier).

This will help open up the innovation space, promote dual-use technologies, and allow for more input, particularly from innovative smaller players. Such competition would give public organisations greater choice, access to novel technologies, and ultimately drive down costs. The technologies and capabilities that come out of such a process can also be used to create business opportunities for private companies and tax revenue for public bodies.



New partnership models

The challenges that unearthing space's potential presents must be addressed across existing borders. Traditionally, these borders have been geographic or political, but today they are more often commercial. This is largely because closer alignment between trade, industrial and defence policies will require consultation with businesses. Every organisation will have its own ambitions for space, but the changes required for success in this domain are universal and so are many of the drivers behind them.

One of the most prevalent drivers is the growth of grey zone conflict. Underhanded grey zone actions seek to achieve their means as expediently as possible, and through whatever channels are most vulnerable - maintaining deniability and conveniently skirting around the conventional laws of armed conflict. Space is fast becoming the perfect breeding ground for this type of campaigning, where satellite jamming and spoofing devices are now part of the everyday arsenal. Plus, dual-use technologies allow malicious actors to disguise a suite of counter-space capabilities in orbital assets. As a result, adversaries are increasingly incorporating space as part of the combination of tactics they can use to destabilise enemies, targeting both military and civilian assets in equal measure. Resilience to an attack on either is therefore increasingly important. Private companies, no matter how well capitalised, will simply not be able to repeatedly replenish space assets that have been disabled by hostile actors.

An increased reliance of the global economy upon space systems is another driver. Financial transactions, communications, agriculture, GPS and transportation are only possible through the exploitation of space. Compounding

this is our unequivocal reliance on space as a component in national critical infrastructure - from the electric grid to traffic light systems. It has been estimated by the US Congressional Research Service (CRS) that \$1.6 trillion of annual US business revenues depends on satellites. A National Institute of Standards and Technology (NIST) study estimates that by 2017, GPS generated roughly \$1.4 trillion in economic benefits since being made available for civil and commercial use in the 1980s. And, although there are - of course - back-up systems in place, the cumulative effects of an outage across interdependent networks would throw defence and commercial infrastructure into disarray. Too much focus on space as a strategic military asset could slow innovation, but too much focus on unregulated commercial innovation could make space a treacherous and unsafe domain in which to operate. Awareness of this precariousness has led to the simmering anxiety around potential conflicts and the growing need for private and public organisations to work together on better space legislation. Today that simply does not happen frequently enough.

These growing risks should propel alliances and collaboration across public and private entities, so they can assure both space-based technologies and the ground-based services they enable. But creating more partnerships is not the answer. Private and public players need to explore smarter models of integration that enable better outcomes.

Policy changes are one way to encourage this. Governments around the world should create space policies that stimulate new forms of integration between public and private sectors. They must use policy to provide long-term commitments and clearly articulated requirements for wider industry in space. UK policymakers have fired the starting gun, announcing an intention to bring together military and civil space policy for the first time, culminating in the UK's first national space strategy, due this summer. That follows a UK Integrated Review, released earlier this year, that talked about 'burden-sharing partnerships' and a strong sense of collaboration for the space domain. Its other priorities include the grey zone, space debris and dual-use technologies. In the US, the National Space Defense Center is a joint effort between the US DoD, various US government agencies, the intelligence

community, and private industry - it aims to research US space vulnerabilities and develop tactics and doctrine to deal with potential attacks. Such initiatives must become the norm. Governments have the power to regulate, enable, fund, entice and inspire. With the right approach to policy, they can (and should) be the stimulant for pioneering collaborations that break new ground.

If governments have the levers, private industry has the entrepreneurial experience. Interoperability and joint development programmes are becoming the cornerstone of modern industrial design and manufacturing. Automotive brands are creating new vehicles together, technology firms are sharing expertise to tap into new markets and engineering companies are building communities to provide a single source for a complex range of specialist services. Industry knows how to collaborate in new ways and deliver advantage to public sector customers. Unfortunately, the public sector can thwart such collaboration through an archaic procurement system based on 'adversarial' contracts that promote detailed commercial requirements above strategic outcomes. Progress in space requires this to change. If new models of public-private partnerships are to work, the public sector procurement environment needs to encourage a more strategic approach to this shared challenge - one that matches the speed at which the space sector moves.

Technology requirements need to be identified at a higher level, and agreements should be based on delivering outcomes, not technical specifications. As well as engendering deeper trust and a more closely bound relationship, it will allow for greater flexibility and agility in project development - which is so vital, given the pace of change in this domain.

Beneath all of this lies the technical ability for organisations from different environments to share information. New partnership models may work in principle, but in practice they need to function tactically, day-to-day. As mentioned earlier, the challenge of switching from proprietary to open systems remains prevalent in the space sector, where competitive edge and protecting intellectual property still come before collaborative advantage for most commercial organisations. That must change. Space may be a potential treasure trove of commercial opportunity, but it also harbours risks to a safe and secure society. Embracing more interoperable technology will ease the path to collaborative efforts that maximise the former and mitigate the latter. This is an area that has been explored and tested considerably in many commercial environments. In space, as in defence and security, it is still not the de facto option.



Key recommendations

Our protracted transition to a space-faring civilisation will be, arguably, one of humanity's greatest and most difficult endeavours. We've come far since the early days of space exploration, but what humankind has achieved is a fraction of what is possible if efforts can be more coordinated.

This report has covered a lot of ideas for how to stimulate that coordination and allow it to be successful. Together they point to five wider, overarching recommendations that will help establish an environment best suited to progress across the domain.

Make defence and security a unifying force in space

Programmes for space vary tremendously, as do the objectives of the different players involved in their delivery. So, finding a common thread is an important way to stimulate a more integrated approach. Defence and security requirements can be that thread. No endeavour in space, be it public or private, can sustain vulnerabilities that place it at risk from either honest mistakes or malicious actors. Protecting space-based assets, their associated ground-based infrastructure, and the services they enable, can be a way to focus disparate mindsets on a shared challenge - one which has become all the more prevalent since the emergence of dual-use technologies above the Earth. And the pervasive threat of space debris gives such synergy even more impetus. Defence and security considerations must, therefore, become a focal point for collaborative efforts - and a trigger for more joined up thinking when it comes to planning and executing operations in space. By doing so, innovation and expansion in the domain will become led by a shared mission, not simply the needs of individual organisations or sectors in silo.

Embrace space heritage

It is natural to look forward when seeking to progress. But, as the private sector rapidly asserts its position in the diverse ecosystem of space, those trying to advance their role in this domain should understand the importance of learning from what came before. Indeed, much of what the commercial sector is trying now, agencies and governments have done before. What is different is the technology, materials, risk appetite and safety elements - but the results are largely the same. Rather than doing the same again - private players must look back to see where these experiences could impart valuable learnings to shortcut today's innovation process. So, whilst the days of governments needed to initiate, fund and operate everything are gone, heavy reliance on them for resources, guidance and support will, and should, continue. Their strong history in space; their experience in contested domains, and their knowledge of the legislative and regulatory levers that can be pulled should not be omitted by businesses with a development deadline to meet. Not only is this sharing of knowledge essential, it needs to occur at the outset, not as an afterthought.

A collaborative environment for dual-use innovation and technology

The integration of technologies will be a defining factor in the success (or failure) of tomorrow's space ecosystem. Many in-service space systems are built using legacy proprietary architectures. This makes it hard to integrate a range of different technologies and systems to improve functionality, and get them to work together. The growth of dual-use technologies has exacerbated this issue. They require a more complex mix of technologies to safely and securely power a broader range of services, both in space and on the ground.

Things are starting to change. Technological interoperability is beginning to improve. NASA's Ingenuity helicopter (which recently flew on Mars) was built using the Linux operating system and it has announced the planned VIPER Lunar Rover will employ open source software to navigate the lunar surface. This should be encouraged to evolve into best practice, and embedded into the design/development programmes of public and private space systems.

That will enable different platforms and assets to access a common communications, command and control architecture, which, in turn, opens the door to a space ecosystem based on open architectures – where digital blueprints are shared so trusted organisations can work collaboratively on them.

The challenge is one of balance. How can such critical systems be open enough to enable greater integration, whilst remaining closed enough to minimise the exposure to cyber vulnerabilities and protect the core installed performance? The opportunity is considerable. If attitudes to open architectures improve, the ability to undertake collaborative development of innovative equipment and services will result in much more effective progress in both. Finding a way to achieve the required balance of openness and security is achievable, and should be a priority.

Listen before legislating

It is not just technology that needs to be designed to enable collaborative requirements. Global policy should as well. Whilst governments will be under pressure to build more rigorous space laws and regulations, they must continue to work closely with industry and commercial partners to ensure these regulations and laws empower all players in the space ecosystem. Bureaucracy that acts as a barrier to some, and not others, undermines collective activity. Incentives that favour one community does damage to the prospect of broader integration. Defence and security companies are one group in a unique position to input into this process because they understand a wide variety of customer needs. They operate across multiple domains simultaneously, understand both the military mission and the technology roadmap, and bridge the gap between commercial output and public sector input effectively. As policy and regulation is amended or enacted over the next decade, those responsible for everything from public finance models to security strategy and planning need to drive greater engagement with private entities to create more representative outcomes.

Combine skillsets to achieve better outcomes

An advantage of closer integration between the public and private sectors is the opportunity to combine skills. For example, effective space-based data exploitation is fast becoming a decisive weapon in defence and security, but it is not a skill traditionally abundant in the public sector. The private sector is a hub for talent in data science, but many businesses lack the expertise and confidence to take on the daunting regulatory hurdles associated with data collection and exploitation. The public sector cannot compete with the private sector for technical skills, but does wield the legislative weight to negotiate legal pitfalls. It also possesses an understanding of the public it serves and the 'big picture' when it comes to political and socio-economic issues. Integrated, these strengths could be a formidable force. Both public and private organisations need to identify what skills they have and what skills they lack, then work together to plug the gaps and move forward together. That requires greater understanding of their respective ways of working, their constraints, and their influences.



Conclusion

Today, space has entered an entirely new phase of international commerce and competition. The overwhelming expenses, barriers to entry and complexities of space have largely abated, and the domain is more open, more viable, but all the more congested, than ever before. From one end of the community to the other we can all see that action must be taken today to engender consolidated, collaborative efforts between government and private industry for space to fulfil its potential.

In this report we have looked at a number of factors that influence how that needs to happen, and in conclusion we can highlight three fundamental principles that fuel them all - one is conceptual; one is about process; and the third is technological.

Conceptually, all players in this domain - be they nations, companies, or institutions - need to view defence and security as a common set of challenges and opportunities that bind them. Space advancements expose a need for greater space security. The intensity and proliferation of offensive capabilities in space will continue to up the ante, notch by notch. Some nations, particularly Russia and China, are pursuing non-destructive and destructive counter-space weapons, like jammers, lasers, or anti-satellite (ASAT) systems, along with cyber-attack capabilities - cyber also being within the capacity of smaller, non-state actors. Any organisation operating in this domain is vulnerable to such threats, no matter its size, industry or experience.

We must work collaboratively across boundaries to provide faster, smarter, and more effective ways for everyone to protect what matters most.

From a process perspective, new ways for large and small organisations to work together will underpin the most effective collaboration. Connecting innovative SMEs with entrepreneurial mindsets, and established primes, with a track record of performance and quality, offers a way to enable the industry to extract the best of both worlds. Novel partnerships will be essential for unlocking the potential that joined-up thinking from SMEs and large established organisations bring. Existing models are starting to break new ground here and SMEs are becoming engaged in greater numbers. These models should be explored further.

Technologically, dual-use technologies can be the catalyst for all of the factors covered in this report. They encourage new partnership models, new financing models, and new ways of sharing knowledge. They drive collaborative innovation programmes that are 'mission-led', and they are often fuelled by past lessons that showcase where dual-use would have delivered better results.

Acknowledging these themes will be pivotal for both commercial prosperity and military capability in space. The changes required are not simple, nor are they solely technical or process-driven. They are also cultural and require a shift in mindset to trigger a subsequent shift in outcomes. That is in the hands of us all – the complex mix of players in this domain.

**Continue as we are, and we will experience slow, staccato progress.
Collaborate, and anything is possible.**



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