Future Issue

Space-Based Warfare

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The Future of Space-Based Warfare in Brief

State and non-state actors use space for a variety of commercial, civil, and military purposes. The spending on space exploration and space technology research and development (R&D) is on the rise again, after a brief lull at the end of the nineties. Also, an increasing number of actors have access to space. Up till now, none of these actors has stationed weapons in space. However, a combination of rapid advances in technology, rising space budgets and dedicated efforts by numerous state and non-state actors to gain a space capability may produce serious threats to the future security environment. Moreover, the conduct of contemporary conventional warfare increasingly depends on space-based assets for logistics support, reconnaissance, and command & control. Some authors expect space to become the locus of future warfare. This could lead to grave consequences for national and international security.

The Big Picture

Parameters

State Actors in Space; Terrorist Actors in Space; Commercialisation of Space; Tension Civil-Military Use of Space; Weaponisation of Space; Military Capability Dependent on Space; Arms Race; International Cooperation; Domination of Space

Drivers

Transparency; Absence of a Clear Legal Regime; Space Economy; Technological Development; Security Environment; Political Choice

Effects

The onset of an arms race and its impact on the distribution of power within the international system; the offence-defence balance and its impact on strategic stability; and the weaponisation of space and its impact on space economies and societies on earth

Somewhere deep inside defence departments, hidden from the general public's eye, heated debates on the modus and locus of future warfare are taking place. One of the central topics of these debates is the weaponisation of space and the likelihood of space-based warfare.

While space has been militarised since the 1950s – when the USSR and the US used satellites to spy on each other – up till now states have refrained from weaponising space. On the other hand, states increasingly use space-based military assets in current conventional warfare for logistics support, reconnaissance, and command & control of military operations. The importance of space-based assets for the conduct of contemporary warfare and their relevance for military superiority highlight the potential impact of space-based assets on issues of national and international security. This has led some participants involved to observe that it is not a question whether space will be weaponised, but rather when this will happen.

Militarisation of space refers to the support of earth-based weapon systems by space-based assets. Weaponisation of space is usually defined by the instalment of weapons or weapon systems, either based on land, sea, air or in space, that are either **directed at** space-based assets or **dependent on** the physical use of space in order to function[1]. Space weapons can thus be directed from earth-to-space, space-to-earth, and space-to-space, as long as space forms an essential part of the trajectory or system. According to some definitions, weapons that are directed from earth-to-earth (through space), such as intercontinental ballistic missiles (ICBMs), already amount to the weaponisation of space[2]. This *Future Issue* holds that space has not been weaponised in the sense that so far earth-to-space, space-to-earth, and space-to-space weapons have not been introduced in space yet.

Foresights disagree on the likelihood of the future weaponisation of space understood in this sense. While pessimists refer to the dismal failure of The Hague Convention of 1899 that sought to establish a ban on the "launching of projectiles and explosives from balloons"[3], optimists point out that after more than four decades the 1967 Outer Space Treaty still hasn't been violated. Regardless of how the future of space weaponisation and space-based warfare may unfold, it will most certainly affect a number of fundamental pillars of the current international order.

HCSS reviewed 33 foresight studies published since 1999, analysing the discourse surrounding the weaponisation of space and the likelihood of space-based warfare in the next 10-20 years (2020-2030). This *Future Issue* summarises the main insights in five sections:

- A sketch of a number of trends in the use of spatial orbits surrounding earth.

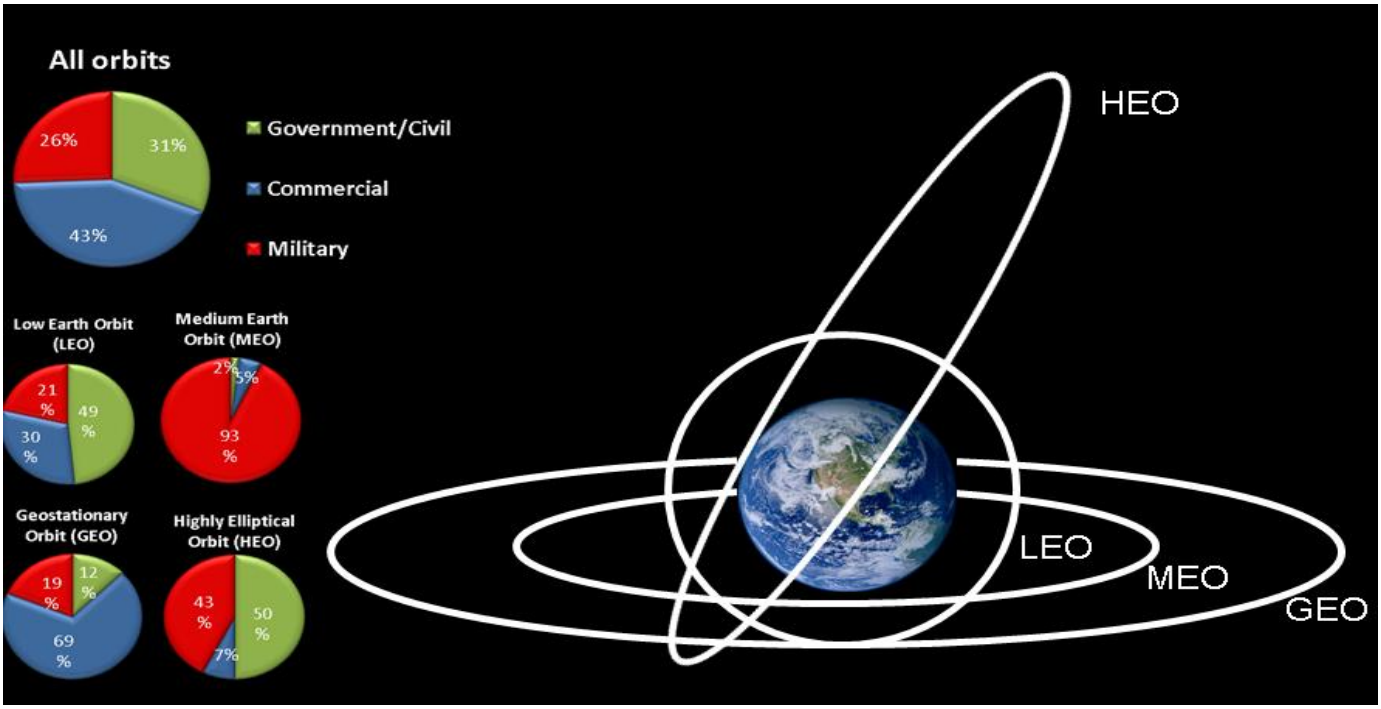

Figure 1. Four orbits and their uses (government/civil, commercial, military). Low Earth Orbit (LEO) ranges from 100-2,000 kilometres and is relatively easily accessible in comparison to the other orbits; Medium Earth Orbit (MEO) ranges from 5,000-10,000 kilometres, and Geostationary Orbit (GEO) is around 36,000 kilometres. The fourth category is the Highly Elliptical Orbit (HEO) which, as its name indicates, follows a different rotation course.

- An evaluation of the parameters relevant to the future of space-based warfare.
- An examination of the drivers fuelling these parameters.
- A look at four possible "future space worlds".
- An analysis of the applications and implications of the weaponisation of space for security on earth.

Earth's Geospatial Orbits and their Various Uses

Earth's spatial orbits are used for commercial, civil, and military purposes. Commercial satellite operators provide a wide range of services that are used in modern, information-driven economies, such as the utilisation of GPS satellites for land, sea, and air traffic navigation, imaging satellites for retrieve-and-rescue and cell phone services. Governments and organisations employ satellites for civil purposes, including the monitoring of weather conditions, the supply of aerial missions, city planning, news and entertainment images, and communication satellites for broadband internet and cell phone services. Governments and organisations employ satellites for civil purposes, including the monitoring of weather conditions, the supply of aerial (spatial) images, and scientific research. Military satellites are used in most of these ways, apart from reconnaissance, surveillance, command & control and logistics support. These satellites are located in roughly four different orbits: Low Earth Orbit (LEO), Medium Earth Orbit (MEO), Geostationary Orbit (GEO) and Highly Elliptical Orbit (HEO). The geospatial location of conflict regarding the use of these spatial orbits will undoubtedly depend on how these orbits are used and who has access to them. States with basic launch capabilities, for instance, are only capable of bringing satellites in LEO. The other three orbits remain beyond their reach. The detonation of a nuclear device in LEO by a rogue state (or perhaps even a terrorist actor) would destroy the majority of satellites in this orbit (see the section Wild Cards)[4]. Figure 1 shows the four orbits with the respective satellite type distribution (commercial, civil, and military).

Actors in Space

An increasing number of actors, both state and non-state, have access to space for a variety of military, civil and commercial purposes. In 2008, ten states, the European Space Agency (ESA), and more than a dozen private companies had proven launch capabilities[5]. The current distribution of power in space is unipolar. It is based on the overwhelming superiority of the US in space assets and R&D investment. The US has significantly more resources in space than its peers, while vastly outspending them. With some exceptions, the foresights generally assume that a unipolar distribution of power is *ceteris paribus* associated with a peaceful space environment, while bipolar and multipolar distributions are more likely to lead to conflict. However, during the past decades some

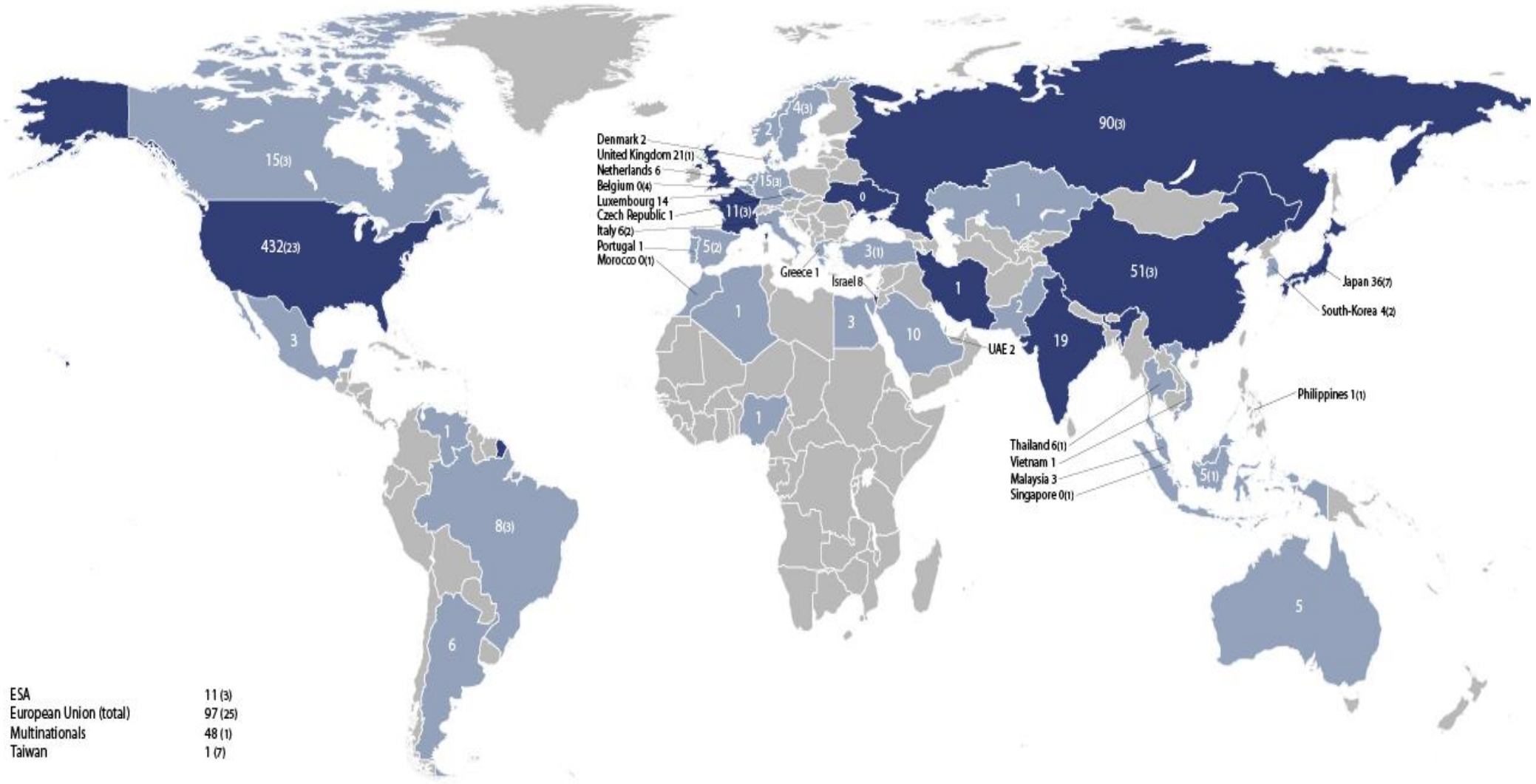

Figure 2. Satellites owned by state actors. Between brackets are satellites that have shared ownership (2008)[6]

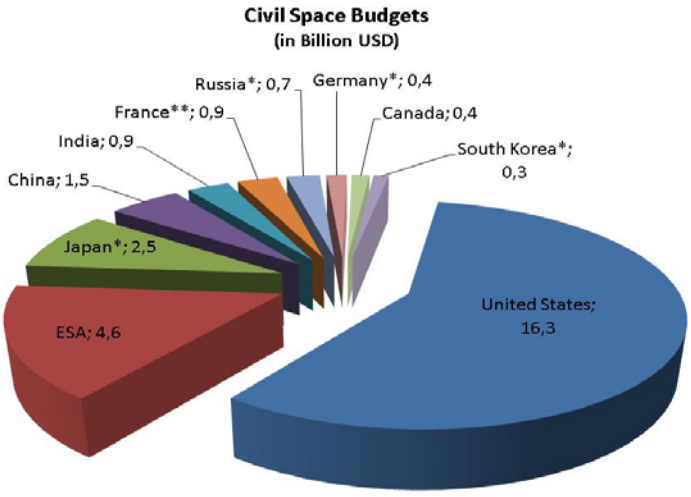

Figure 1. Civil Space Budgets.

medium and small powers have also gained access to space. Iran launched its first (civilian) satellite in 2008. Another 34 states and a growing number of multinationals, without launch capabilities of their own, have space-based assets[7]. Figure 2 lists the number of satellites owned by state actors.

Space budgets

The spending on space exploration and space technology R&D is on the rise again after a brief lull at the end of the nineties. The US space budget increased by over 50% between 2000 and 2007 to a staggering USD 40 billion, most of which is paid by the Pentagon[8]. Although all states have so far complied with the terms of the Outer Space Treaty – which, amongst other things, prohibits the stationing of nuclear weapons in space[9] – some states are already using space for military purposes, ranging from reconnaissance and intelligence-gathering to communication in wartime. The fear of actual weaponisation is rampant, though, especially after the Chinese ASAT test in January 2007, when China shot down a defunct weather satellite, a feat that was followed by a similar US test in February 2008. China and the US showed that if the worst comes to the worst, they will be ready and able to weaponise space. An examination of the military expenditures of states with launch capabilities reveals that these states have dedicated significant sums to space activities.[10]

While the US space budget accounts for roughly 80% of the OECD countries, states like Russia[11], India[12] and China[13] have also significantly increased their space expenditures. The ten largest national or regional civil space agencies had a total budget of over 28 billion USD in 2007 (see Figure 3).

The space industry

The commercial sector has also seen steady growth during the last decades. The economic volume of the space sector – with OECD annual space budgets totalling around USD 60 billion, a space manufacturing sector employing roughly 100,000 people and a total satellite stock in space worth over 200 billion USD – is increasing year by year[14]. Total revenues peaked at 123 billion USD in 2007, which is an increase of almost 50% over the period 2000-2007 (see Figure 4)[15]. Revenues are expected to rise substantially in the near future. Some forecasts estimate the space industry will be worth over a trillion USD by 2020[16]. However, insiders disagree about the long-term economic prospects of the commercial satellite industry. Some of the services offered from space could ultimately be provided by alternative assets based within the earth's atmosphere (e.g. fibre-optic cables for communication, aerial photography for observation[17]). Commercial satellite operators already provide a vast range of services in communication and navigation that are indispensable to the functioning of modern, information-driven economies[18]. A sudden satellite blackout could have severe consequences for the way our society is organised[19].

A greater dependency of societies on space-based services may, on the one hand, reduce the odds of space-based warfare, especially if all states stand to lose equally, but this dependency will also increase the cost to society in the event of space-based warfare.

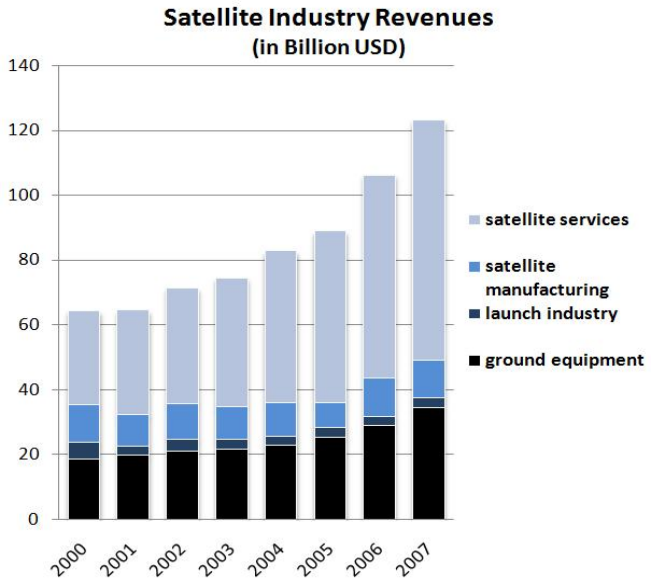

Figure 4. Satellite Industry Revenues (2000 - 2007).

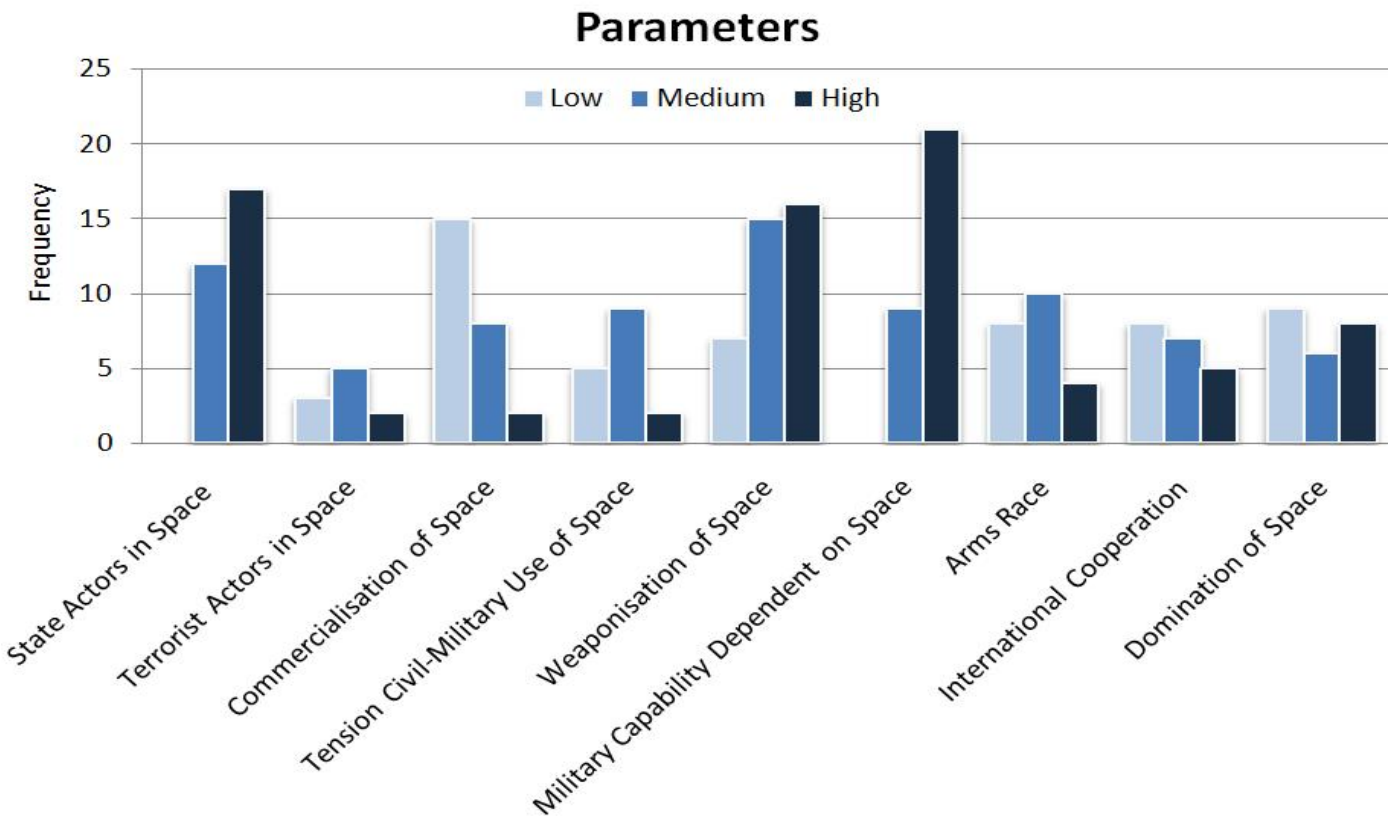

Figure 5. Parameters - the parameters have been valued on a 1-3 scale, the 3 indicating a future world in which space-based warfare is more likely to occur (the coding scheme for commercialisation and international cooperation runs has been reversed, with 3 indicating a low degree and 1 indicating a high degree of commercialisation/international cooperation).

The combination of rapid advances in technology, rising space budgets and dedicated efforts by numerous state and non-state actors to gain a space capability may produce serious threats to the future security environment. This issue will be further explored in the sections below.

Parameters

HCSS analysed the abovementioned foresight studies in search of 'robust' findings, i.e. insights that emerged in a large number of these foresight studies. These insights were coded into nine individual parameters (see Appendix A for a detailed description). The parameters were subsequently rated on a 1-3 scale, the 3 indicating a future world in which space-based warfare is more likely to occur. To give an example: if in a particular foresight study an arms race was considered to be very likely, it was scored as a '3' on the Arms Race parameter. In this way, a list of the most relevant parameters was created, while simultaneously charting the foresight community's assessment of the values of these parameters (see Figure 5).

The following nine issues are at the heart of the foresight debate on space-based warfare: *State Actors in Space, Terrorist Actors in Space, Commercialisation of Space, Tension Civil-Military Use of Space, Weaponisation of Space, Military Capability Dependent on Space, Arms Race, International Cooperation,* and *Domination of Space*.

This section briefly summarises the foresight community's assessment of these parameters. The following sections will elaborate on these assessments:

- The foresights generally predict a greater number of *state actors in space*. It is expected that state actors will have increased access to space, either directly by means of their own launching capabilities, or indirectly by outsourcing the launch of their assets to countries or companies with launching capabilities. For example, North-Korea is planning to launch its first satellite into orbit in 2009[20]; Brazil, South-Korea and Kazakhstan are developing launching capabilities[21]; and a number of countries, like South-Africa and Mexico, are actively planning new space activities[22]. The foresights expect this trend to continue in the coming decades.
- Additionally, there is common agreement that space will be increasingly used for *commercial purposes*.

- It is therefore not unlikely, according to the foresight community, that *tension will arise between commercial/civil and military uses of space*.
- The foresights diverge on the degree to which *terrorist actors* will have access to space. It is expected that terrorist actors will be able to temporarily jam satellite transmissions (according to some reports they already are) or even transmit their own signals from a hijacked satellite. This is, however, a different matter from a terrorist actor with its own satellite and perhaps even weapon assets in space. The foresight community is divided and inconclusive on the future of terrorism in space.
- Centrepiece to the debate is whether space will actually be weaponised. In general, the foresights incline towards the view that *weaponisation of space* will take place, the vast majority expecting a medium or an extensive weaponisation of space.
- It is commonly believed that the *dependency on space assets* to achieve military superiority in terrestrial operations will be medium to high.
- The foresights diverge on the likelihood of an *arms race in space*. A sizeable minority expects no increase in the level of armament competition, the majority of the foresights expect increased armament competition in space, while only a small minority foresees a new arms race in space.
- Nor do the foresights agree on the extent to which *international cooperation* both in the civil and the military realm will take root.
- With respect to the *distribution of power* in space, the foresights differ and describe unipolar, bipolar as well as multipolar future space systems. With some exceptions, the foresights generally assume that a unipolar distribution of power is *ceteris paribus* associated with a peaceful space environment, while bipolar and multipolar distributions are more likely to lead to conflict.

Drivers

HCSS analysed the foresight studies in search of 'drivers', the factors behind the future weaponisation of space and the future of space-based warfare (see Figure 6). The following six key drivers of the future of space-based warfare are identified: *Transparency, Legal Regimes, Space Economy, Technological Development, Security Environment,* and *Political Choice*.

- *Transparency* is considered to be one of the key determinants of the viability of a treaty on the weaponisation of space. Transparency, or rather the lack thereof, will be a major issue in the

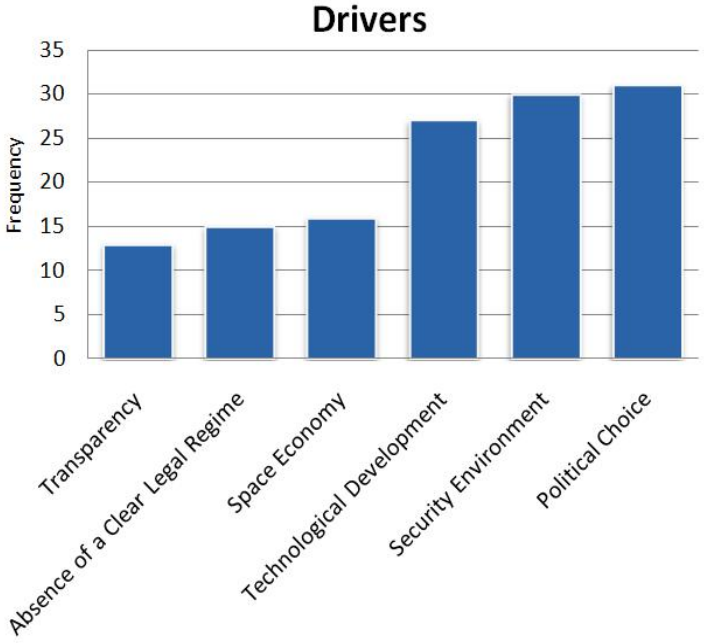

Figure 6. Drivers - Transparency; Absence of a Clear Legal Regime; Space Economy; Technological Development; Security Environment; and Political Choice.

weaponisation of space, as well as in the prevention of collisions between objects in space.
- The existence of *legal regimes* that clearly outline legitimate uses of space affects the decision-making processes of a state on whether to weaponise space. Current regimes, however – both at the national and the international level – are vague and incomprehensive. International cooperation is embedded in a framework of international legal regimes and international organisations. Appendix C gives an overview of the most important legal regimes and organisations dealing with space issues.
- A third driver is the *degree to which the 'regular' economy on earth will come to rely on space-based assets*. The enormous increase in the use of satellites for navigation purposes by the public at large is just an example of the growing dependency. While it is relatively uncertain how this dependency will develop in the future, it is clear that this will have an effect on the commercialisation of space.
- *Technological development* affects a wide range of parameters, from launch capabilities of state and non-state actors and the type of weapons that states will be able to produce to the cost of maintaining space-based assets.
- *The security environment* and *the political choices* made by states are closely connected. If the *security environment* is hostile and characterised by intense (military) competition, this will undoubtedly influence the *political choices* these states will make

with respect to the weaponisation of space and – if need be – the actual use of these weapons.

- *Political choices* are at the root of national security strategies and investment decisions, which are instrumental in defining the future of space-based warfare.

Wild Cards

Any meta-analysis of the foresight community's combined expert judgment runs the risk of missing out on numerous factors that could also partially determine the weaponisation of space and the future of space-based warfare. In order to highlight this notion of deep uncertainty, a number of wild cards are included. Wild cards describe events that are not very likely to occur, but if they do they will have enormous consequences. An invasion of earth by technologically superior aliens is an example of a wild card. From the foresights and other relevant information, a number of wild cards were distilled. These wild cards (High Altitude Nuclear Detonation (HAND); Space Abandonment; Space Weather; Hidden Space Weaponisation; and Space Debris) are described in Textbox 1.

Scenarios

The analysis of the drivers and the parameters reveals that the future of space-based warfare is far from written in stone. Whether space wars will eventually occur and how they will be fought, is determined by a combination of drivers and parameters. The following section will briefly sketch four scenarios to help understand the possible interaction between the drivers and the parameters. These scenarios do not claim to predict what the future will look like, but are rather meant to be seen as specific aggregations of the foresight analyses that illustrate different ways in which the future may unfold.

The scenarios have been drawn up along two main dimensions: international cooperation and weaponisation of space. International cooperation is plotted on the horizontal axis ranging from no cooperation at all (left) to extensive cooperation (right). Weaponisation of space is plotted on the vertical axis, ranging from no weaponisation at all (bottom) to extensive weaponisation of space (top). Within these dimensions we have varied the different parameters that are salient in the foresight discourse to produce scenarios that describe four future worlds of 2025: *Space Hobbesia, Armed Peace, Kantian Space* and *Back to the Future* (see Figure 7).

Space Hobbesia

Giant leaps in technological development have significantly lowered costs for aspiring space entrants, introducing such applications as *Rods from God* (hypervelocity rod bundles), chemical lasers, and killer satellites in earth's geospatial orbits. With tremendous implications for strategic interstate stability, that is. The conduct of future warfare relies on information superiority based on space assets such as reconnaissance and communication satellites. The use of satellite bandwidth per US military member increased

Wild Cards	
High-altitude Nuclear Detonation (HAND)	A high-altitude nuclear detonation (HAND) destroys a number of satellites with its blast, radiation and EMP. The ensuing radiation belt eventually renders the majority of LEO-orbiting satellites useless. Satellite replenishment from earth would be impossible for up to two years as a result of the raised peak radiation flux.
Space Abandonment	In the 15th century the Chinese Ming dynasty dominated the high seas when economic and political dismay led to the abrupt abandonment of all naval expeditions. Sovereign space actors could yet be forced in this age to make a similar decision and abandon the further exploration, militarisation and weaponisation of space.
Space Weather	Solar flares of unprecedented magnitude produce devastating solar storms that affect space assets as well as earth-based power networks. The loss of space assets and the societal havoc on earth combined constitute a major setback to the prospects of future space developments.
Hidden Space Weaponisation	Technological sophistication and dual-use applicability lead to a gradual evolution from a weapon free space to a hidden space weaponisation. The use of undetectable and untraceable space weapons eventually leads to a tipping point and ushers in an era of all-out space weaponisation.
Space Debris	The amount of space debris increases rapidly – either from deliberate or accidental satellite destruction – and is insufficiently dealt with. Space eventually becomes inaccessible for orbiting satellites for an unknown length of time.

Textbox 1. Wild Cards.

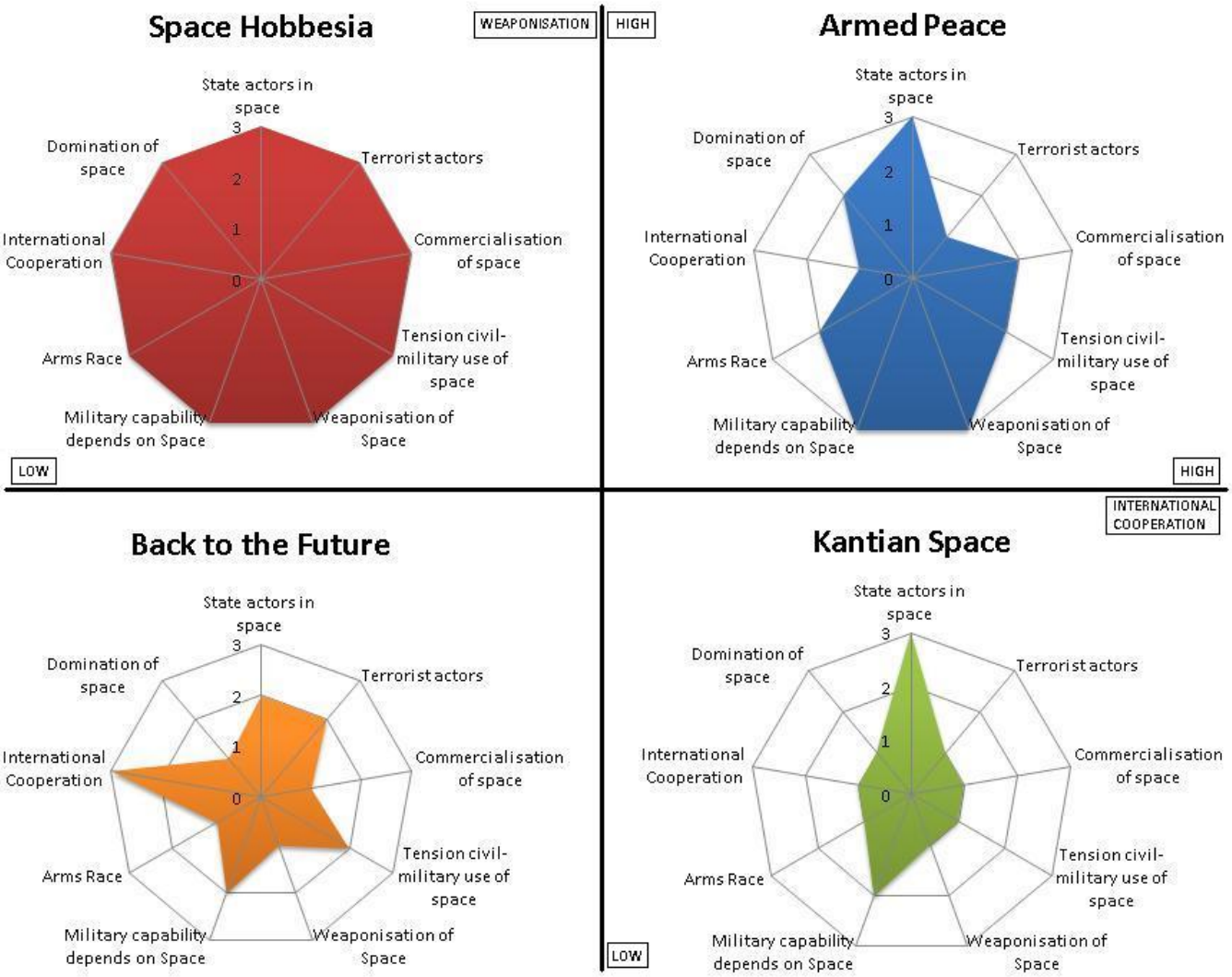

Figure 7. Four Futures for Space

fiftyfold between the Gulf War and Operation Iraqi Freedom and has risen exponentially since[23]. Meanwhile, non-state (terrorist) actors have gained the capacity to launch attacks in space. They form an important threat to space-based assets of nation-states. A global arms race has started, forcing initially reluctant states to participate and invest heavily in military space assets. No single state is able to dominate space. The resulting friction amongst and between the civil and the military use of space-based assets halts the further commercialisation of space that seemed to gain momentum in the first decade of the 21st century. A number of commercial services that previously relied on space-based assets (i.e. navigation, communication) have come to rely on earth-based applications, with grave consequences for space R&D, whose main source of funding continues to be governments. Space technology innovations trickle from the military to the civil domain, rather than the other way around, as was predicted in 1990s. The arms race also stimulates the further exploration of space and the colonisation of planetary bodies. Although the push to go beyond the unknown frontiers leads to the discovery of vast, untapped resource basins, it also reinjects the risk of territorial wars of the past into the international system.

Armed Peace

In some ways *Armed Peace* resembles the situation of the later stages of the Cold War. Space is dominated by two major powers, China and the US (although one insider reports that especially India is rapidly expanding its space capabilities and may turn out to be a major space power instead of China). Both powers have populated space with a wide range of weapons, but they cooperate closely to prevent space-based war. The number of state actors with a presence in space has continued to rise, but due to various international regimes space is beyond the reach of terrorist actors. While tension between the civil and the military use of

space applications exists, there is still sufficient room for commercial operators. For one thing, this tension arises

from the dual use of some applications such as imaging satellites. Practically anybody is able to get useful military information from commercial satellites. Back in 2007 the insurgents in Iraq were the first to use satellite pictures from Google Earth to plan attacks on British troops in Basra. Other non-state actors followed this trend[24]. The civil/commercial sector also depends on the military that still controls access to some technologies (the US, for instance, still hasn't released its control over GPS). The expectation is that civil-military tension will arise due to the limited availability of bandwidth space, orbital slots and radio frequencies. Interference of radio frequencies of different operators, disputes over allocated orbital slots and the continuous growth in military demand for bandwidth space could become bones of contention. In the future, space technology innovations may originate in the commercial sector and find their way into the military domain, marking a significant departure from the past. This may produce situations in which state actors are left without any control over the use and the distribution of certain space technologies and applications.

The great dependency of societies and economies on space-based services makes them extremely vulnerable to the intentional or non-intentional disruption of these services. Space R&D funding comes from a mix of state and private actors and innovations emerge from both the civil and the military domain. While in the armed peace scenario the states in the international system have succeeded in preventing the outbreak of space-based warfare, it is a very fragile peace indeed, whose relative stability – the Cold War revisited! – could be shattered at a moment's notice.

Kantian Space

Kantian Space is characterised by a benign and calm space environment. Space is populated by a large number of space actors, both state and non-state, and it is broadly used for commercial purposes. The space environment is dominated by one hegemonic state that supports international cooperation and guarantees stability. As a result, states refrain from the weaponisation of space. Space access to terrorist actors is restricted due to the fact that states have deployed excellent situational awareness resources and are able to detect any unregistered intrusion of space. The billions of euros saved by the states on the development of space weapons are invested in international collaborative efforts to explore the boundaries of our galaxy, as well as in space-based applications. States build science fiction-like objects such as space elevators – consisting of a 100,000 kilometre tube of nanomaterial, capable of transporting payloads and personnel into space – which is projected to be technologically feasible within the next decade[25]. Earth's geospatial orbits are swamped by a wide variety of applications that enhance safety and security on earth, ranging from natural disaster early warning systems and climate change monitoring devices, to situational awareness assets – accessible to all states – that register and publish all movement of weapons and forces on earth. The enhanced situational awareness reinforces a further decline in interstate conflict, while raising the capability of the UN and regional organisations to detect which intrastate conflicts threaten to flare up.

Back to the Future

In *Back to the Future* the world is not very different from its current configuration. Space has not (yet) been weaponised. Some international cooperation takes place in the realm of space, but it is minimal and covers only a small part of space-related activities. Since space has not been weaponised, states obviously haven't entered into an arms race. Still, the threat of the onset of an arms race always looms on the horizon. One single state dominates space, although multiple state actors do maintain a presence in space. Earth's geospatial orbits are increasingly used for commercial purposes and some tensions arise between the civil and the military use of space. In addition to states acquiring launch capabilities, the number of private corporations that are able to provide these services is growing as well. Technological developments have provided terrorist actors with (earth-based) space access and terrorist groups incidentally target and hijack communication satellites. Back in 2009, there had been several reports on the Sri Lanka-based Tamil Tigers temporarily taking control of an Indian satellite and transmitting television images[26]. This practice has become increasingly common, as are the less harmful incidents with unauthorised actors temporarily jamming satellites[27]. While space-based warfare in this particular scenario is out of the question, states increasingly rely on space-based assets to conduct military operations on earth.

	Objective	Application / System	Time Estimate
Space Control	Protection	Radiation Hardened Micro-processors	2015
		Enhanced Surface Coating	2015
		Radiation Remediation	**2009 (tested)**
		Counter EMP measures	Present
	Negation	Electronic Jammers/ Spoofers	**since 2004**
	Surveillance (Space Situational	Femtosatellites (Distributed Real-time Awareness Global Network in Space)	2025 - 30
		Infrared/ visible fluoride fiber sensors (FFL)	2030
		Space Fence	Present
		Smart Dust / Nano-sized particles	2025
Space Support	Operating	Artificial Intelligence Systems	2030
		Small Satellites	No Estimate
	Launching	Electrostatic Thrusters based on Nanoparticles	2015
		Carbon Nano Tubes (CNT) in space material	
		Space Elevator	*2025*
		Evolved Expendable Launch Vehicle (EELV)	**Present - 2020**
		Space Nuclear Reactors (SNR)	*Uncertain*
Force Enhancement	Navigation	Jamming-protected GPS Satellites	**2011**
		Galileo (GNSS) EU navigational satellite system	**2010 - 2012**
	Missile Warning	Space Tracking and Surveillance System	**Present**
		Microsatellite propulsion systems to increasing maneuverability of space assets	No Estimate
	Communications	Space-based Synthetic Aperture Radar (SAR)	No Estimate
		Electronic Safeguards for Communication system	
Force Application	Weapon Applications (directed energy)	Space-based Lasers with lethal force	2025
		Lethal Energy Beam	2025
	Weapon Applications (kinetic energy)	Missile-launching capable satellites	2025
		Hypervelocity Rod Bundles ("Rod from God")	*Uncertain*
		Space-based Interceptor (SBI)	2010-2012

Figure 8. Military space applications (fourth column: time estimates in bold indicate a high degree of certainty regarding the date of implementation, while italics indicate a high degree of uncertainty).

Security Effects: Applications & Implications

Security applications

An in-depth analysis of the foresights and other relevant sources (see Bibliography) revealed a variety of applications that are likely to be employed in the realm of space. These space applications were divided into the four categories used in the US National Space Policy of 2006: space control, space support, force enhancement and force application. Space control concerns the use of space: surveillance, negation and protection of space (assets); space support is all about the launch and operation of space assets; force enhancement currently means war-fighter support: communications, missile warning and navigation; and force applications concern space weaponry. Time estimates in **bold** indicate a high degree of certainty regarding the date of implementation, while *italics* indicate a high degree of uncertainty (see Figure 10).

Security implications

The analysis of the abovementioned drivers, parameters and scenarios shows how the weaponisation of space may have far-reaching consequences for national and international security. Various space applications, especially those used for force enhancement and force application, will be crucial when it comes to shaping the future security environment. However, it is impossible to describe all possible security implications across the different future worlds. This section will therefore address the most salient ones within three broader themes:

- The onset of an arms race and its impact on the distribution of power within the international system.
- The renewal of the offence-defence debate and its impact on strategic stability.

- The weaponisation of space and its impact on space economies and societies on earth.

Arms race in space and the global distribution of power

If a state stations weapons in space, this may be perceived by other states as an attempt to alter the balance of power. In periods following technological innovation states may find a window of opportunity to gain a decisive advantage over their opponents and invest heavily in a specific technology/application. The naval arms race between the UK, Germany and Japan, for example, gained momentum after the introduction of the *Dreadnought* in 1908, while the *missile gap* debates following the nuclear revolution in the US prompted massive investments in intercontinental ballistic missiles (ICBMs) in the 1950s. The weaponisation of space by a single state may create some dynamics of its own, and spark an arms race between states in the system.

Eventually, assuming that only a small number of states will be able to participate, and keep up this arms race, the international distribution of power in space may come to resemble a Concert of the Great Space Powers. Also assuming a growing dependency on space-based assets for force enhancement, this Concert will control all communication and imaging satellites in case of war, blinding the states that did not participate in the arms race in the first place and rendering them powerless. If they succeed in introducing into space offensive applications like hypervelocity bundles (*Rods from God*) or space-based lasers, while at the same time fielding a credible ballistic missile defense, the members of the Concert may achieve true deterrence, while providing themselves with a true global strike capacity and giving them free rein against every other opponent.

In this respect, transparency of the space environment may be very relevant. States need to be able to verify whether their opponents are complying with the terms of any treaty. The Strategic Arms Limitation (SALT) treaties of the Cold War era were only possible because none of the parties was able to interfere unnoticed with the technical means of verification of its opponent. This transparency was one of the key foundations of strategic stability in the Cold War in the post-Johnson years, enabling both parties to verify that each was living up to both the spirit and the letter of the treaty[28].

The resources currently employed by states do not provide sufficient space situational awareness (SSA) to monitor the spatial orbits in the earth's vicinity and determine whether states actually refrain from weaponising space. There is no robust oversight and tracking regime of all objects in orbit. The US Air Force made improving its SSA a top priority after the 2007 Chinese anti-satellite (ASAT) test. It identified four major shortcomings, namely, the ability to track foreign satellites, to predict the effects of space weather, to keep tabs on orbital debris and the ability to reconstitute a corps of space intelligence analysts[29]. The US Space Surveillance Network is currently relying on ground-based radar transmitters and receivers, but a future system is expected to be space-based, using a constellation of microsatellites that provide real-time awareness, such as the Distributed Real-time Awareness Global Network in Space (DRAGNETS) project anticipated around 2025[30]. Central to this debate remains whether states will have sufficient SSA, to reliably verify that other states do not covertly build up their space capacity.

The offence-defence balance and the issue of strategic stability

The weaponisation of space will undoubtedly rekindle the offence-defence balance discussion. The offence-defense balance discussion revolves around the question whether certain technologies favour the offending or the defending party, and how this affects the likelihood of conflict and war. In the absence of sufficient SSA transparency is low, which favours the offence, since actors are able to attack each other without giving away their identity. This applies both to space-to-space attacks through ASAT nanosats or space mines, earth-to-space through jamming devices, and space-to-earth through applications such as envisioned by the brilliant pebbles system in the 1980s. This will raise the chance of conflict if it (re)introduces first strike instability to the international system. Moreover, war games conducted by the Pentagon at the beginning of the 21st century showed a remarkable tendency to escalate into nuclear war, both in space and on earth, when space weapons were used[31]. However, if states have increased SSA and have a comprehensive space tracking and surveillance system in place, this might favour the defence, in that it raises transparency and excludes the possibility that a state is able to attack another state unnoticed (whether in space or on earth). Also, enhanced monitoring and reconnaissance capabilities would enable states to detect troop and weapon movements at an early stage and prove to be excellent early warning indicators of the advent of conflict. This would turn the tables of the offence-defence balance in favour of the latter. If states are able to field credible ballistic missile shields, the

defence would be strengthened even further. Whichever way things will turn out, the types of applications that will be employed in space and on earth will affect interstate strategic stability.

Weaponisation versus commercial utilisation of space and the fate of modern economies

The weaponisation of space will likely constrain the use of space for commercial purposes. First, it may exacerbate conflicts over the frequencies for communication. Second, it will increase the dual use tension that exists in applications with both civil/commercial and military potential. Third, it will raise the insurance fees for the satellite sector. Countries will be forced to make a trade-off between investing in the development of space assets of their own or reliance on commercial providers to render the services they need (i.e. communication, imaging, etc.). At present, states pursue different strategies (France, for instance, invests in national space capabilities, while the UK outsources the majority of its space activities to the commercial sector). If space is weaponised, countries that rely on commercial providers may need to reconsider their space strategies. In case of an actual war in space, space assets in the hands of commercial actors are likely to be nationalised immediately. If hostilities in space happen fast and space-based services will be disrupted, it is unclear whether modern economies and societies will be robust enough to continue to function without trouble. Communication and navigation providers may have their capacity to deliver services practically annihilated overnight, meaning a total disappearance of their revenue-base. If – by accident or by intent – a nuclear device is exploded in space, LEO may be rendered useless for a period of 18-24 months. It would mean a significant setback for the entire commercial satellite industry, as investors will likely be hesitant to invest in the presence of such risks, in addition to significantly increasing the cost of insurance[32]. It would also necessitate people to return to the reliance on earth-based assets for services that are currently delivered through space-based assets. Last but not least, weapons cost money and regardless of potential future spin-offs, any weaponisation of space means that fewer funds will be invested in the use of space for other purposes like sustainable development and space tourism.

Conclusions

- There is general agreement that a greater number of state actors will become active in space, and that space will increasingly be used for commercial purposes. As a result, modern societies and economies will come to depend more on space-based applications, thus raising their vulnerability in case of disruption of these services.

- It is not unlikely that tension will arise between the commercial/civil and military uses of space, due to the limited availability of bandwidth space, orbital slots and radio frequencies and in some cases because of the dual use of some applications such as imaging satellites. In the future, space technology innovations may trickle down from the commercial to the military domain, potentially leading to situations in which state actors no longer have control over the use and the distribution of certain space technologies and applications.

- Current and future warfare will increasingly depend on information superiority relying on space assets such as reconnaissance and communication satellites. Although the foresight community is divided and inconclusive on the future of terrorism in space, the common expectation is that states, in one form or another, will seek to put weapons in space somewhere in the next two decades. They diverge, however, on the likelihood of an arms race in space and the extent to which international cooperation both in the civil and the military realm will take root. With respect to the distribution of power in space, the descriptions vary from unipolar to bipolar and multipolar systems.

- The commercial use of space is considered to be at odds with space weaponisation. More tension is expected to arise between the two. Space warfare may seriously affect the commercial use of space through its impact on the willingness of investors to allocate resources in the commercial satellite sector and will probably mark a return to the reliance on earth-based assets. In case of a nuclear detonation, LEO may become useless for a period of 18-24 months, involving tremendous cost to satellite owners.

- SSA will be a key factor in determining the broader security implications of the weaponisation of space. SSA capacities will likely affect the form of an arms race and interstate strategic stability in the light of the offence-defence debate.

- The future of space weaponisation and space-based warfare may unfold in a variety of ways. The security implications derived from a number of applications

expected to arrive before 2030 will evolve around three broader issues that will affect key issues in national and international security. These are the onset of an arms race and its impact on the distribution of power within the international system, the renewal of the offence-defence debate and its impact on strategic stability, and the weaponisation of space and its impact on space economies and societies on earth.

Concluding, the weaponisation of space and the future of space-based warfare will become a prominent subject for national security establishments and the industries that serve them.

Appendix A – Definitions Parameters

1. State Actors in Space

This parameter analyses the extent to which space is accessible to state actors, either for commercial or military-political purposes. Foresights that see a low accessibility of space are coded as 1, those that see an increased accessibility of space are coded as 2, and foresights that see a high accessibility of space and to numerous parties are coded as 3.

- Space utilisation/accessibility (state-actors)
  - 1 – Low/No Increase
  - 2 – Moderate Increase
  - 3 – High Increase

2. Terrorist Actors in Space

This parameter analyses the extent to which space is accessible to terrorist actors. Foresights that see no accessibility of space are coded as 1, those that see an increased accessibility of space are coded as 2, and foresights that see a high accessibility of space are coded as 3.

- Space utilisation/accessibility (terrorist actors)
  - 1 – Low/No Accessibility
  - 2 – Increased Accessibility
  - 3 – High Accessibility

3. Commercialisation of Space

This parameter analyses the extent to which space will be used for commercial purposes. Space may be increasingly accessible to commercial and civil actors. The rise in the number of commercial and civil actors may change the way space is used and can thus diversify possible outcomes or scenarios. The foresights that see no increase in the use of space for commercial purposes are coded as 1, those that see an increased use of space for commercial purposes are coded as 2, and foresights that see a massive increase in the use of space for commercial purposes are coded as 3.

- Increased use of space by non-state actors for commercial and civil purposes
  - 1 – Low/No increase
  - 2 – Moderate Increase
  - 3 – High Increase

4. Tension Civil-Military Use of Space

This parameter analyses the possible tension between commercial/civil and military uses of space. A foresight is given a score when it acknowledges a relation between the two.

Foresights that see a shared use of space without tension are coded as 1, those that see a shared use of space result in a moderate degree of tension are coded as 2, and foresights that see a shared use of space result in a high degree of tension are coded as 3.

- Civil-Military Tensions in the Use of Space
  - 1 – No Tension
  - 2 – Medium Tension
  - 3 – High Tension

5. Weaponisation of Space

This parameter analyses to what degree foresights envision the weaponisation of space. Weaponisation of space can be seen as the instalment of weapon systems that depend, at least partially, on the use of space in order to function. The focus of the weapon systems can be either *earth-to-space, space-to-space or space-to-earth,* and may have defensive and/or offensive purposes.

Foresights that envision no weaponisation of space are coded as 1, those that see a partial or moderate increase in the weaponisation of space are coded as 2, and foresights that see an extensive weaponisation of space are coded as 3.

- Weaponisation of space
  - 1 – No Weaponisation
  - 2 – Partial/Moderate Weaponisation
  - 3 – Extensive Weaponisation

6. Military Capability Dependent on Space

This parameter analyses the extent to which space-based capabilities and control over space are seen as preconditions for military superiority on earth. Foresights that emphasise the importance of control see space as the 'new high ground' of future warfare. Military capabilities will increasingly depend on space-based applications.

Foresights that see no growing dependence on space-based capabilities are coded as 1, those that see future military systems partially depend on space assets are coded as 2, and foresights that see the future of military capabilities as highly dependent on space assets are coded as 3.

- Control over space/use of space becomes an essential element in military strategy and forms the precondition for military superiority
    - 1 – No growing dependence on space-based capabilities
    - 2 – Partially dependent on space-based capabilities
    - 3 – Highly dependent on space-based capabilities

7. Arms Race

This parameter analyses the probability of an arms race in space. The Chinese ASAT attack on its own satellite in 2007, and the US attack on its satellite in 2008 may mark the beginning of a low-level arms race in space. Foresights that dismiss the likelihood of an arms race in space are coded as 1, those that foresee increased military competition are coded as 2, and foresights that consider an arms race in space likely to happen are coded as 3.

- Arms race/military competition in space
    - 1 – Arms Race Unlikely
    - 2 – Increased Military Competition
    - 3 – Arms Race Likely

8. International Cooperation

This parameter analyses the extent to which there will be international cooperation in the realm of space for both civil and military purposes. Foresights that see extensive international cooperation in between states, including worldwide implementation of treaties regulating the weaponisation of space, are coded as (1), those that see some international cooperation are coded as (2), and foresights that see a very low to no level of international cooperation at all are coded as (3).

- International cooperation in the use of space
    - 1 – Extensive International Cooperation
    - 2 – Some International Cooperation
    - 3 – Low/No International Cooperation

9. Domination of Space

This parameter analyses the future distribution of political and military power in space. Foresights that see a continuation of US domination of space are coded as 1, those that see a bipolar power distribution in space (e.g. the rise of China and/or Russia in addition to the dominance of the United States) are coded as 2, and foresights that see multiple actors in space, all projecting their military and political power, as 3.

- Competition for space supremacy by one, two or many
    - 1 – Unipolar: US domination continues
    - 2– Bipolar: rise of China and/or Russia in addition to US
    - 3 – Multipolar: multiple actors in space

Appendix B – Foresights (alphabetically)

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Air University, "Blue Horizons Paper: Commercial Eyes in Space", 2008

Air University, "Blue Horizons Paper: Improving Satellite Protection with Nanotech". 2007

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Astropolitics, "The Advent of Space Weapons", 2003

Brookings, "China, Space Weapons and US Security", 2008

Brookings, "The State of Space", 2006

Center for Strategic and Budgetary Assessments "The Revolution in War", 2004

Center for Strategic and International Studies, "Space and National Security", 2007

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Economists for Peace and Security, "Space, Security and the Economy", 2008

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Spacesecurity.org, "Space Security", 2008

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UNIDIR, "Secure in Space The Next Generation", 2008

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World Security Institute, "China's ASAT Test: Strategic Response", 2007

Appendix C – Treaties and organisations"[33].

TREATIES	DESCRIPTION
Outer Space Treaty 1966	The most important and comprehensive document on outer space, this treaty represents the primary basis for legal order in the space environment. Its preamble states that "mankind has an interest in maintaining the exploration of space for peaceful purposes". The key articles secure the free access to space for all nations and prohibit the deployment of Weapons of Mass Destruction (WMD) in space and the military use of the moon.
1967 Astronaut Agreement	Secures the security of astronauts and the ownership over spacecraft – whether on sovereign or on foreign soil – of the participating states.
1972 Liability Convention	Establishes a liability system for the activities of launching states in outer space, making states responsible and liable for damage caused by any of their space assets.
1975 Registration Convention	Requires states to maintain national registries of objects launched into space.
1979 Moon Agreement	Additional explicit agreement on the prohibition of aggressive behaviour on and around the moon.

UN ORGANISATIONS	DESCRIPTION
UN General Assembly: Committee on Disarmament and International Security Committee on Peaceful Uses of Outer Space (COPUOS)	The main deliberative organ of the United Nations on issues of space security. While the decisions of the Assembly are not legally binding, they are considered to carry the weight of world opinion.
Conference on Disarmament: Committee on the Prevention of an Arms Race in Outer Space (PAROS)	Established in 1979 as the primary multilateral disarmament negotiating forum. While the CD has repeatedly attempted to address the issue of the weaponisation of space, there has been no progress on space issues in 30 years, despite efforts to move forward on the PAROS mandate.
International Telecommunications Union (ITU)	Assigns radio frequencies and orbital slots to space actors who want to bring a satellite into orbit.

The international legal regime, formed by these treaties, establishes several specific rights and obligations of spacefaring nations. First, all states have the right of access to space, while any national appropriation of objects or territory in space is illegal. Second, space is to be used only for peaceful purposes and to be free of any WMD. The generalised and indefinite terms used in these treaties, however, have left much room for subjective interpretation of – and therefore contention over the actual meaning of these rights and obligations. There is no official definition of where space begins, for instance, and while Russia interprets 'peaceful' as 'non-military', the US defines it as 'non-aggressive' – leaving room for defensive military use of space[34]. The Outer Space Treaty of 1967 is still the main legal source for space activities. It prohibits the stationing of nuclear weapons in space in addition to the colonisation of celestial bodies, but it does not make any mention of conventional weaponry. Efforts to strengthen the legal regime have so far proven unsuccessful. The Conference on Disarmament (CD), which was established in 1979 as the primary multilateral disarmament negotiating forum, has initiated efforts to prevent an arms race in outer space (PAROS) in 1985, but there has not been a single unanimous declaration since[35]. In the UN General Assembly almost all countries, including China and Russia, support yearly motions that seek to outlaw the weaponisation of space, showing a general inclination towards peaceful uses of space. Only the US and Israel have either abstained from voting or have cast negative votes since 1995. The US has justified its rejection of official limitations of space weaponising by referring to its own unique security considerations due to its asymmetric dependence on space[36]. The 2006 US National Space Policy came to include additional mission areas – space control and force applications – that clearly reflected the Bush administration's intent to secure its superiority in space. One of the obligations of the Secretary of Defence, cited in this policy, is to "[d]evelop capabilities, plans, and options to ensure freedom of action in space, and, if directed, deny such freedom of action to adversaries"[37]. In March 2009 the Obama administration presented a new space policy that sought "a worldwide ban on weapons that interfere with military and commercial satellites"[38].

Textbox 1. Overview of the most important treaties and organisations dealing with space issues.[39]

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