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Space

Satellites, Space Exploration, and the Netherlands' National Security

Key takeaways

Issue brief

- The Netherlands is critically dependent on the positioning, navigation, and timing, communication, and remote sensing services provided by satellites.
- The Netherlands is not alone in its dependence. More than 80 states have launched satellites into orbit.
- Satellites are threatened by the militarization of space, space debris, and legal ambiguity. Interstate competition means that more and more states are likely to obtain ASAT weapons in the future, meaning the immediacy of the domain's military importance is on the uptick.
- The Netherlands boasts a productive and innovative industry which can contribute to the development of technologies for removing space debris from orbit, among others.
- Space is also of relevance because of the natural resources contained in celestial bodies. These include asteroids such as Ceres, but also Luna and Mars.
- The resources contained in celestial bodies will add trillions to the global economy. The space economy is expected to increase from a $339bn market in 2019 to a $2.7tn market in 2045.
- International legislation of space is weak. The Outer Space Treaty incentivizes competition in the form of a space race.

Recommendations

- The Netherlands' dependence on satellites operated by 3rd parties leaves both its civilian and military sectors vulnerable to a "collateral" disruption.
- To mitigate this, the Netherlands should asses the likely impact of a disruption and put contingency plans and mitigating procedures in place.
- Such mitigation measures should strive to proactively soften the economic and political impacts of such a disruption on the one hand, and the military impacts on the other.
- The Netherlands should formulate national legislation geared towards plugging lacunas and addressing ambiguities concerning resource extraction and ownership rights in outer space, with the long term goal being the revision of the Outer Space Treaty.
- The Dutch space industry currently generates €600mn in annual revenues. Because it is capable of producing all components of modern nanosats, it offers the Netherlands an opportunity to further its goal of sourcing military hardware domestically and to increase its strategic autonomy.
- To achieve these goals, the Netherlands should work to support Dutch startups looking to work on space technologies. The retention of Dutch talent should constitute a priority within the context of this initiative.

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Strategic Alert

Introduction

The economic relevance of space is substantive and growing. Currently, space's value is primarily derived from satellites orbiting Earth. A 2019 study found that 87.5% of the $277bn in revenues generated in space could be attributed to commercial satellite services.[1] These services are of critical importance to the functioning of the (inter)national economy. Positioning, timing, and navigation (PNT), communications, and Earth observation services form the backbone of many essential processes, such as fleet management or bank transactions. They are also key to the Netherlands' military capabilities. Several strategic processes, from the execution of beyond line of sight (BLOS) operations to nuclear deterrence, are dependent on satellites. In the long term, space is also likely to play a role in the global energy transition. For example, the rare earth elements (REEs) contained in celestial bodies are in increasingly limited supply on Earth and are required for many renewable technologies.

SATELLITES ACCOUNT FOR 87.5% OF SPACE REVENUES

As interstate competition heats up, an increasing number of states – more than 80 in 2018, compared to 50 in 2008 – have launched satellites into orbit.[2] This, along with reductions in the cost of launching payloads, introduces both threats and opportunities from the Dutch perspective. Well-managed, commercially proactive, and internationally regulated initiatives to unlock and safeguard the space domain's huge potential could contribute to European strategic autonomy, to the energy transition, and to a continued economic growth. Badly managed initiatives could see an intensification of inter-state competition and the deterioration of public services.

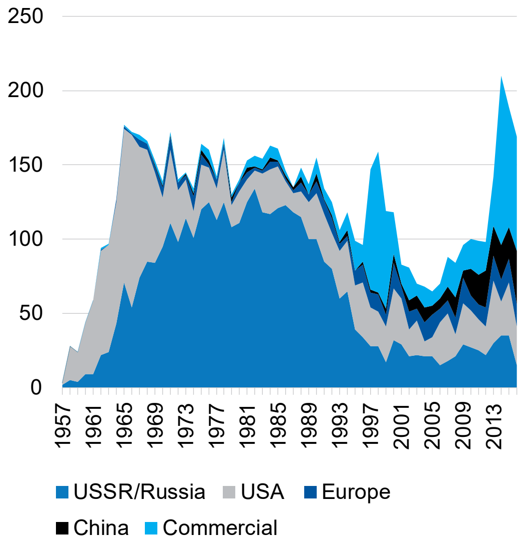
MORE THAN 80 STATES HAVE LAUNCHED SATELLITES INTO ORBIT

Activities in orbit

Operations taking place in orbit around Earth are almost exclusively associated with satellites, the use of which has become far more commonplace in recent years. Since the Soviet Union launched Sputnik in 1957, the number of satellites in orbit has increased to 4,987 in 2019.[3] Almost half of this growth occurred post-2008. Private sector actors account for the majority (see Figure 1).[4]

THERE ARE CURRENTLY 4,987 SATELLITES IN ORBIT

Figure 1 **Number of satellites launched by actor, 1957-2016**[5]



Broadly speaking, satellites' economic and military value derives from three functions. The first is positioning, timing, and navigation (PNT), which is essential for the functioning of much of our critical infrastructure. The second, satellite communications, enables both military communications BLOS and over the horizon (OTH) operations. Third, Earth observation and remote sensing is crucial for the continuous monitoring of a wide range of phenomena. Predicting the likely onset and spread pattern of wildfires, conducting precision agriculture, and intercepting modern nuclear delivery vehicles are examples of problems whose solutions depend almost entirely on remote sensing.

PNT, COMMUNICATIONS, AND REMOTE SENSING

Picture 1 A satellite orbits Earth[6]

PNT and Communications

Economic relevance of PNT

A 2011 study found that 6-7% of Western countries' GDP (more than €800bn in the EU alone) and 11 out of 16 critical industries are dependent on PNT to function.[7] Power grids, telecom networks, and the global financial system could all grind to a halt without PNT-delivered inter-device synchronization. The Netherlands is among the world's most connected countries, meaning that the degree to which its population relies on the modern services-based economy is extremely high.[8]

6-7% OF WESTERN COUNTRIES' GDP DEPENDS ON PNT

Synchronization across the Dutch power grid

The Dutch power grid would be unable to function without PNT. Control room applications such as data acquisition, supervisory control, and status reporting have a time synchronization requirement of approximately one second. Event reporting processes, which play a key role in coordinating grid-level power sharing in the event of a disruption, depend on a time synchronization of one millisecond. The synchrophasors that allow power grid operators to correct for mismatches between supply and demand across the grid have a time synchronization requirement of one microsecond. These systems facilitate the process of transferring energy from one area of the grid to another – something which makes them key to mitigating the impact of disruptions. Without PNT, these transfers would be delayed, the grid would over or under-produce power. The country would see widespread power outages as a result.

PNT technologies' relevance to the Dutch power grid is set to increase as a result of the country's transition to renewable energy sources such as wind turbines and solar panels, which generate power intermittently.

Dutch telecom networks and the financial sector

Precision timing facilitates the public switch telephone network (PSTN). The PSTN is the aggregate of the world's telecom networks, operated by different companies. Networks on the PSTN are connected to switching centers which make use of the timestamps provided by GPS satellites to connect users to one-another.

Of equal importance to the Netherlands is the synchronization of cell sites. Devices communicate with the cell tower nearest to their location, a variable which the system solves for based on GPS data. Without space-based precision timing, it would be impossible to call someone connected to another cell tower or on another network.

POWER STATIONS, TELECOM, AND FINANCE ALL BREAK DOWN WITHOUT PNT

Within the financial sector, GPS transmissions are used to timestamp and validate business transactions. Precision timing constitutes a key ingredient in the automation of these processes; their execution would be subject to significant delays and to an increased risk of fraud in its absence.

Military relevance of PNT and communications

Without PNT, Dutch military operators would be unable to communicate with one-another or to take advantage of advanced systems such as the F-35. PNT signals are critical to the Armed Forces' command, control, communications and computers capabilities, making them indispensable to any large-scale military operation.

Navigation

Dutch F-16s rely on PNT signals to navigate airspaces and to strike targets with pinpoint accuracy. The platform is equipped with a range of armaments which make use of GPS signals to lock on to an operator-defined set of geographic coordinates.[9] The Royal Netherlands Navy's four *Zeven Provinciën*-class frigates – which are expected to be in service well past 2025 – are also highly reliant on PNT. The ships use PNT signals to navigate the world's oceans and are armed with a host of weapon systems that would be unable to function without them.

Picture 2 Dutch Navy frigate Tromp sails in 2017[10]

Communication

In complex warfighting scenarios, success depends on the capability to connect (delocalized) sensors and weapons across the coalition's accumulated forces. Satellite communications are essential for doing so. An F-35 flying over a mission area is unable to communicate with a command center in the Netherlands directly without satellite arrays such as the US-operated Milstar. Military communications are transmitted by radio waves which rely on line-of-sight transmissions, meaning that the curvature of the Earth limits their range. The Milstar constellation, which the Netherlands makes use of and which will be replaced by the Advanced Extremely High Frequency (AEHF) in the near future,[11] consists of six satellites. Taken together, they enable radio communications between most locations on Earth.

THE DUTCH ARMED FORCES RELY ON THE MILSTAR CONSTELLATION TO COMMUNICATE

Encryption

Even when two transmitters are within view of one another, as might be the case between two or more F-35's flying in formation, they rely on satellites to communicate. This is because military communications are shielded from interception by frequency hopping within a spread spectrum. The precise frequency over which these communications occur is determined by transmission security (TRANSEC) keys. TRANSEC keys depend on precise timing because the to-be-used frequency changes based on the time. This means that any operator which cannot keep precise time will be unable to send or receive communications.[12]

Remote sensing

Economic relevance of remote sensing

The electromagnetic and light sensors fitted to remote sensing satellites allow for the continuous monitoring of real-world phenomena. Almost everything – gasses such as carbon monoxide and carbon dioxide included – interact with electromagnetic signals by either absorbing or emitting specific wavelengths.[13] The data generated by remote sensing satellites is used for everything from agriculture and forestry, environmental and coastal monitoring, to disaster response planning, law enforcement, city & urban planning, and archaeology,[14] among others. A few concrete applications are outlined below.

REMOTE SENSING HAS BOTH MILITARY AND ECONOMIC APPLICATIONS

- **Weather forecasting and oceanographic research**. Remote sensing can be used to quantify a range of variables pertaining to weather and climate, including wind speed, atmospheric pressure, surface temperature, oceanic currents, temperatures, and wave direction & height. This data is routinely being used to predict the onset and model the likely path of hurricanes such as Irma,[15] which caused over $3bn in damages to St. Maarten in September 2017.[16]

- **Modelling wildfire risk**. Remote sensing can be used to provide information on the (type of) vegetation present within a given area. The EU's Joint Research Center maintains a Normalized Difference Vegetation Index, which provides insights into the density and health of vegetation.[17] Combined with surface temperature predictions, this data can be used to model not only whether an area is at risk of wildfires, but also the path a wildfire might take when it breaks out.

- **Precision agriculture**. The use of satellites and its remote sensing capabilities can be used to provide farmers with information on soil fertility and moisture, growing rates, and crop ripeness.

Compared to older technologies, satellite data has the benefit of improving geographical coverage and giving experts access to larger, more detailed datasets. This notwithstanding, the current-day impact of remote sensing technologies is primarily driven by lower costs of launching payloads into space and increased computing capacities. Taken together, these reduce both public and private sector actors' barriers to accessing remote sensing data, unlocking a wide range of potential use cases, commercial and otherwise.

PROACTIVE CLIMATE POLICIES BENEFIT FROM REMOTE SENSING

Military relevance of remote sensing

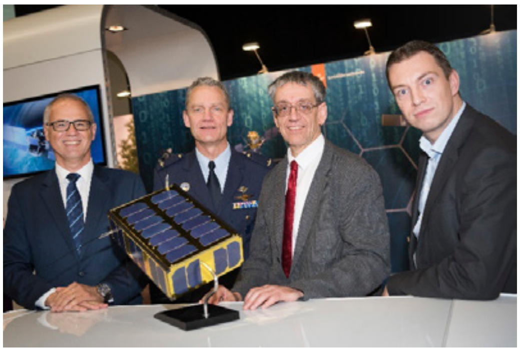
Military remote sensing satellites play a central role in early warning and ballistic missile defense (BMD). BMD remains a core task of collective defense in NATO, with the alliance announcing in October 2019 that the "proliferation of ballistic missiles poses an increasing threat to NATO populations, territory, and forces"[18] and designating space as an "operational domain" in November of the same year.[19]

With advanced technologies proliferating, and the development of a new generation of nuclear delivery vehicles in particular, space-based remote sensing is set to grow in relevance. Two of the most worrisome incarnations of these weapons, hypersonic and nuclear-powered missiles, pose challenges to conventional radar-based detection systems. In the case of hypersonic glide vehicles, this is because current radar technologies are limited by range. The hypersonic delivery systems developed by the US, Russia, and China are all capable of Mach 5, or 6,174 km/h – a speed at which conventional radar systems will detect them only two minutes before impact. Nuclear-powered delivery vehicles raise a similar issue. These weapons can remain airborne for long periods of time, need not follow a ballistic trajectory, and are capable of flying closer to the Earth's surface.

MODERN MISSILES ARE TRACKED BY THEIR ENGINE PLUMES

Within a military context, satellites' Earth observation and remote sensing functionalities also play a central role in intelligence gathering. Pre-deployment intelligence gathering allows for the planning of ground operations and for the identification of potential targets, among others. This is a functionality which the Royal Netherlands Air Force, with the launch of its first nanosatellite (nanosat), the Brik-II,[20] makes extensive use of remote sensing. Brik-II is capable of, among others, capturing high-resolution images of the Earth's surface.

Picture 3 Dutch officials pose with a model of the Brik-II nanosat[21]



Threats to activities in orbit

Satellites in orbit face deliberate threats from state and non-state actors on the one hand and are vulnerable to space debris on the other.

Space security

Recent years have seen states develop their anti-satellite (ASAT) capabilities. These take three forms. First, several states have demonstrated their capability to destroy satellites using Earth-based systems. Second, there is a trend towards states launching dual-use satellites into orbit. Finally, several technologies have been developed with the intention of jamming or spoofing satellite signals. They are outlined in further detail below.

ASAT WEAPONS AND SPACE DEBRIS POSE AN IMMEDIATE THREAT TO SATELLITES

- **Direct-ascent ASAT capabilities**. The US, Russia, China, and India have all demonstrated their capability to down satellites in low Earth orbit (LEO) using ground, sea, or air-based launch platforms. Israel is also likely in possession of direct-ascent ASAT capabilities.[22] In 2008, the US Navy successfully

THE US, RUSSIA, CHINA, INDIA, AND ISRAEL HAVE ALL DEVELOPED ASAT CAPABILITIES

destroyed a nonfunctional National Reconnaissance Office satellite using a single modified tactical Standard Missile-3 launched from an AEGIS-class cruiser. Russia carried out the first successful flight test of its anti-satellite missile, the Nudol, in 2015.[23] The Kremlin's fleet of MiG-31s has also been observed carrying 79M6 Kontakt missiles capable of striking orbits in LEO.[24] China carried out a test of its SC-19 ASAT missile in 2007, during which the missile successfully intercepted and destroyed the FY-IC polar orbit satellite.[25] The Indian Ballistic Missile Defense Programme tested its Prithvi Defense Vehicle Mark-II in 2019, successfully destroying a Defense Research and Development Organization Microsat-r satellite.[26]

Picture 4 Launch of an SM-3 missile[27]

- **Co-orbital ASAT capabilities**. There is a trend towards the deployment of space-based (co-orbital) ASAT systems – often in the form of "dual use" satellites. Satellites can be equipped with anything from chemical sprayers to lasers.[28] The Pentagon announced plans to test a satellite-mounted particle beam in 2023.[29] While the technology is intended to disable enemy ballistic missiles, it could also be used to blind the sensors of or to outright destroy enemy satellites. Russia has several highly maneuverable Inspector satellites in orbit, all of which are equipped with instruments that potentially allow them to disable enemy satellites. In another example, China launched an experimental satellite equipped with a mechanical arm in 2013.[30] The satellite repeatedly grabbed and maneuvered a smaller satellite around.[31] Difficulties distinguishing between space debris and co-orbital ASAT capabilities is one of several factors driving a global increase in demand for space situational awareness (SSA) capabilities.

- **Non-kinetic ASAT capabilities**. Several states have developed capabilities to disrupt satellites' ability to transmit signals. Prominent examples include jamming, spoofing, and EMP weapons. In a jamming attack, a ground-based receiver is prevented from accessing signals by a nearby transmitter, which floods the frequencies it uses to communicate with relevant satellites. In a spoofing attack, ground-based equipment mimics satellite signals. Information can be deleted, changed, or even added.[32] EMP attacks rely on the use of an electromagnetic pulse to temporarily disrupt the functions of or permanently damage an adversary's electronics. EMP attacks exist in both nuclear and non-nuclear varieties. Non-nuclear attacks typically target ground-based infrastructure, and have limited range. Nuclear EMP attacks detonate a nuclear payload in space, resulting in the disruption of both space and ground-based infrastructure.

Space debris

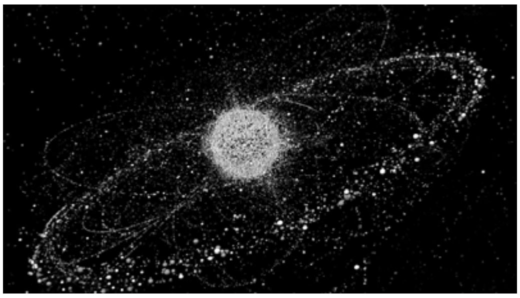
There are currently more than 500,000 pieces of space debris in orbit around Earth, about 30,000 of which are 5-10 cm or larger.[33] Space debris poses a significant risk to satellites. It can be created as a result of collisions between two satellites, as a result of satellites being destroyed by ASAT weapons, or as a result of collisions between a satellite and a wayward piece of space debris. There are several instances of such collisions occurring. A commercially operated Iridium 33 satellite famously collided with a deactivated Russian military satellite, the Kosmos-2251, in 2009. The collision is estimated to have resulted in the creation of approximately 1,000 pieces of debris with a radius of 10 centimeters or more, in addition to many smaller ones.[34]

THERE ARE MORE THAN 500,000 PIECES OF SPACE DEBRIS

The space debris created by collisions travels at 24,000 to 27,000 km/h. At these speeds, even an object with a radius of three millimeters can penetrate a satellite. The impact force of objects with radii of five millimeters is akin to being hit by a bus, while a collision with a piece of debris that has a radius of ten centimeters releases energy comparable to that of modern bombs.[35] The so-called Kessler syndrome describes how the destruction of satellites, particularly when combined with increased congestion of space, might result in a long-term chain reaction. Each destruction results in the creation of more debris which, in turn, increases the likelihood of another collision.[36]

COLLISSIONS RELEASE ENERGY COMPARABLE TO THAT OF MODERN BOMBS

Picture 5 An artist's impression of the space debris orbiting Earth[37]



The international legal framework underpinning space travel interacts with and exacerbates the problem of space debris in several ways. First, though the Liability Convention (1972) of the Outer Space Treaty stipulates that states are liable for damage caused by their objects they launch into space, its applicability remains limited in an era where the private-sector actors account for the majority of satellite traffic. It also hamstrings cleanup efforts. Space junk could feasibly be removed from orbit with current technology, but the wording of the existing Liability Agreement precludes any actor *other* than the launching party from doing so. This means that dead and/or deactivated satellites cannot be de-orbited by actors other than those who launched them – something which precludes entrepreneurial startups from working to do so.

THE OST'S LIABILITY AGREEMENT PROMLEMATIZES THE REMOVAL OF SPACE DEBRIS

Opportunities for the Netherlands

The proliferation of activities in orbit introduces several opportunities for actors based in the Netherlands. Dutch companies may provide SSA solutions, satellite production, and the removal of space debris.

Space Situational Awareness

Reductions in the cost of launching satellites into orbit, a likely proliferation in the volume of space debris, and a marked uptick in state-based ASAT initiatives are all factors that are likely to increase the risk of collisions and to drive demand for SSA technologies. SSA helps operators to maneuver satellites to avoid debris by, at least under ideal conditions, providing them with a clear, predictable overview of what objects will be where at any given time. It constitutes one of the ESA's core competencies, receiving €95mn in funding over the period spanning 2016-2020.[38]

While some SSA sensors are space-based, the majority are ground-based radar installations. The SMART-L MM radar system operated by the Royal Netherlands Armed Forces, while originally developed by Thales Netherlands as an air surveillance and anti-air solution, is capable of identifying objects with diameters as small as 5 centimeters. It is a good example of a Dutch-developed SSA solution which may be suitable for export, either as a system or as a service.

SSA IS AN ESA PRIORITY

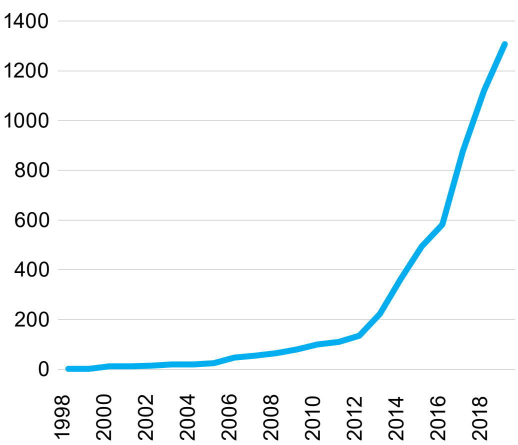
Satellite production

The launch market for these satellites is expected to soar past $62bn by 2030.[39] Nano-satellites (nanosats) such as the Triton-1 developed by ISIS space, a Dutch company, are likely to account for a large share of this market growth because they are relatively quick, cheap, and easy to develop and launch.[40] The number of nanosats in orbit increased more than tenfold between 2010 and 2019, from 99 to 1309. This figure is expected to soar past the 2500 mark by the end of 2023 (Figure 2).[41]

Dutch companies are able to produce all sensors and components on the current generation of nanosats. From the Dutch Ministry of Defense's perspective, this means that the commitment expressed in the 2018 Defence

Industry Strategy to limiting reliance on nondomestic producers can be realistically achieved in the space domain.[42]

Figure 2 Number of nanosat launches by year[43]



Removal of space debris

The value of the space market reached $339bn in 2017. Driven by activities such as the manufacture and use of infrastructure to space-enabled applications such as satellite phones and weather services, it is projected to skyrocket to $2.7tn by 2045.[44] As states scramble to protect the survival of this market, Dutch companies may well find opportunities in the development of technologies capable of removing space junk from orbit. Astroscale, a Japanese company, received $132mn in funding to continue the development of its satellite-based solution in 2019.[45] Innovative institutions based in the Netherlands could follow suit. TU Delft graduates routinely take part in international initiatives, such Ocean Cleanup and Hyperloop, which require a comparably innovative "can do" attitude.

SPACE DEBRIS THREATENS A $339BN MARKET – SOLUTIONS COULD BE LUCRATIVE

Space exploration and exploitation

Not so long ago, it would have been difficult to conceive of a future in which private actors presided over the resources, let along the logistical and technological know-how, to launch payloads into space. Today, neither of these factors pose insurmountable barriers. Elon Musk launched a Tesla Roadster into deep space on a privately-owned "Falcon Heavy" rocket in 2018. Jeff Bezos outlined plans in 2019 to put artificial settlements in orbit around Earth. Bezos and Musk are respectively affiliated with Blue Origin and SpaceX, two of many prominent companies whose activities center around space travel and exploitation of outer space.

SOON, IT WILL NOT BE PROHIBITIVELY EXPENSIVE TO PUT AN ASTEROID IN LUNA ORBIT

Picture 6 A Falcon-9 rocket lands on a drone platform[46]

Relevance of space exploitation

As public and private sectors alike race to explore and exploit outer space, their doing so has both long- and short-term relevance for the Netherlands.

Short-term relevance

The Netherlands' space sector generates a turnover of about €600mn and directly employs over 4,000 highly skilled workers.[47] The sector could see significant growth as a result of commercial space activities kicking off – something which Elon Musk,[48] the United Launch Alliance (ULA), and Merrill Lynch expect to kick-off in earners around 2050.[49] A long period of investments in creating knowledge and experience, developing technologies, products and services, and building and preparing space infrastructure will be required for it to do so. In the short term, space exploration's relevance

PRIVATE SECTOR ACTORS ARE MAKING AGRESSIVES STRIDES IN SPACE EXPLORATION to the Netherlands derives from the economic boons associated with the country's participation in these activities. ULA's "Cislinar 1000" concept foresees these activities as comprising the following in 2025, 2035, and 2050:[50]

- **2025**. Small-scale commercial habitats, such as those proposed by Jeff Bezos, could become a reality. These facilities host commercial research activities and increase space's total population to ±20. Corporations begin limited space manufacturing of protein crystals and semiconductor wafers. State and nonstate actors alike intensify prospecting activities. **The gross space product is approximately $500bn per year**.

- **2035**. Propellant mining and refinery initiates on Luna. Space's population has increased to ±300, and space tourism is commonplace. **The gross space product is approximately $900bn per year**.

- **2050**. The cislunar economy is self-sustaining. This dramatically reduces the costs of ferrying materials from Luna to LEO. There is a permanent lunar habitat. Small-scale asteroid mining means that corporations can start to extract and deliver REEs to Earth. **The gross space product is approximately $2.7tn per year**.

The preparatory activities necessary to realize concepts such as the ULA's "Cislunar 1000" are occurring and attracting funding in the present. There are clear indicators that these institutions' attentions are focused on exploring the feasibility of and facilitating space exploration. A NASA-commissioned study conducted by the Keck Institute for Space Studies at Caltech estimated the costs of "capturing" a 7-meter-wide near-Earth asteroid and putting it into Luna orbit at a relatively modest $2.6bn.[51] European institutions such as ESA have also increased their R&D investments significantly. Research conducted by Bryce Space & Technology indicates that billionaires have stepped up their investments into companies specializing in the development of launch technologies in recent years.[52] Estimates published by the OECD put private-sector actors' contribution to space-related investment at a whopping 16% of the total between 2008 and the present.

Long term relevance

Once the exploration and exploitation of space kicks off in earnest, it will result in the extraction of rare earth elements and water on the one hand, and in off-planet industrial production facilities on the other. Outside of having the potential to add trillions to the global economy, these activities are of high potential relevance to combating climate change.

Resource extraction

Asteroid DA14 – a celestial body half the size of a football field, which passed within 27,680 kilometers of Earth in 2013 – is estimated to contain $195bn worth in metal and fuel.[53] DA14 is one of twelve identified easily retrievable objects that could be captured, mined, and their resources returned to Earth with today's rocket technology.[54] In addition, there are as many as 17,000 asteroids near the Earth which are likely to become accessible for mining with future rocket technology.[55] Mars, Luna, and several of Jupiter's moons are also likely to contain valuable resources.

ASTEROID MINING WILL ADD TRILLIONS TO THE GLOBAL ECONOMY

The commercial benefits of deep-space mining go hand-in-hand with its potential relevance to the long-term functioning of the global economy and to the realization of a global energy transition. Bloomberg New Energy Finance estimated in 2018 that the world's cobalt supply – a metal which is key to the production of li-ion batteries –would likely go into deficit by 2022/2023, and would experience a 149,000 ton deficit by 2030.[56] Several other metals found in asteroids – gold, platinum, iron, nickel, and many REEs included – could see their price per weight ratio decrease by a supply influx from space, making the transition to the renewable energies that rely on them cheaper in the process.

Asteroids are also rich in water,[57] which can be found in hydrated minerals.[58] Some astronomers believe that Ceres – a dwarf planet located in the Main Asteroid Belt between Mars and Jupiter– may contain more freshwater than Earth. Tapping into these resources could facilitate further interstellar travel.[59] Water molecules are comprised of two hydrogen atoms

ASTEROIDS CONTAIN REEs AND WATER – BOTH KEY ENERGY SOURCES

and one oxygen atom. Because hydrogen and oxygen are two of the most abundant elements in modern rocket fuel,[60] accessing the water contained in asteroids is likely to be key to facilitating deep-space travel in the future.

Picture 7 An artist's rendition of a spacecraft on an asteroid mining mission[61]

Threats associated with space exploration and exploitation

Activities relating to space exploration and exploitation introduce two threat categories. On the one hand, state initiatives to establish permanent lunar bases have the potential of endangering satellites and of challenging the existing international legislative framework. On the other, gaps in this legal framework incentivize state and nonstate actors alike to treat space like a "Wild West" and to engage in a confrontational race to the bottom.

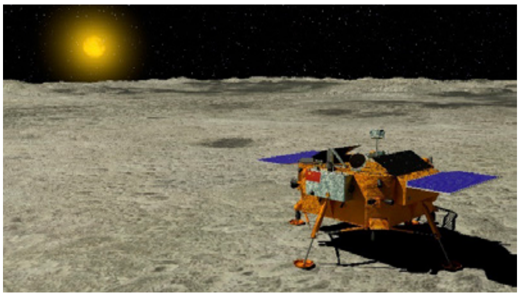
Threatening implications of lunar basing

On January 2, 2019, China became the first country in the world to land a spacecraft on the far side of the Moon.[62] China's lander, the Chang'e 4, is equipped with several sensors which lend themselves well to studying Luna's geophysics and radiation characteristics. Also aboard is a self-contained biosphere which contains various seeds and silkworm eggs, intended to inform Chinese scientists on the viability of artificial habitats. The Chang'e 4 is widely believed to represent a steppingstone towards China's plans for a manned lunar mission and/or for the construction of a semi-permanent outpost on Luna sometime in the 2030s.

BASES ON LUNA RAISE LEGAL QUESTIONS AND FACILITATE NEW TYPES OF ASAT CAPABILITIES

Concerns over the possible military applications of building a military installation on the far side of the moon are widespread. Satellites such as the Queqiao, the communications relay satellite that enables communication with the Chang'e 4, could theoretically slingshot around Luna to be used as an ASAT weapon. They could also serve to support Luna-based ASAT weapons. Outside of allowing for the potential use of hard-to-detect ASAT weapons, an outpost on the far side of the Moon could serve as a facility at which research could be conducted away from prying eyes.[63]

Picture 8 An artist's rendition of China's Chang'e 4 lunar lander[64]



Exacerbating effects of existing space law

China has compared Luna to the South China Sea, and asteroids to the East China Sea.[65] This comparison outlines a factor which is likely to exacerbate both interstate and inter-corporate competition over outer space's resources going forward: that the existing international legal framework is woefully underequipped to regulate these activities in a meaningful way. The Outer Space Treaty (OST) does not correct for many of the activities which are likely to occur in space. Where international law does apply, the combination of ambiguous language and lack of legal precedent means that many of its articles are open to interpretation.

BEIJING HAS LIKENED LUNA TO THE SOUTH CHINA SEA

Lacunas in space law

The OST is riddled with gaps regarding the presence and conduct of actors in space. A clear *lacuna* in international space law emerged when the Falcon Heavy rocket launched a Tesla Roadster into deep space.[66] The prospect of the payload colliding with and contaminating an interstellar body raised questions regarding the degree to which private sector actors are bound by Article IX. The US' legal framework has been designed to ensure

LEGAL UNCERTAINTY INCENTIVISES COMPETITION

the country complies with the OST, and is predominantly geared towards overseeing the launch of commercial satellites.[67]

Congress took steps to provide the US government with the power to oversee commercial actions in space when the House passed the American Space Commerce Free Enterprise Act (ASCFEA) in 2017.[68] Lacunas in the OST mean that the ASCFEA can take many liberties in what it does and does not allow. Countries are likely to continue plugging these holes in regulation in ways which reflect their own interests, influencing the likely scope of future international legislation in the process. Private sector actors may consider space as a "Wild West" equivalent with little regulation to abide to.

Ambiguities in space law

Activities that *are* addressed in the OST are often addressed ambiguously. Under normal circumstances, these ambiguities are dealt with when parties register complaints, something which results in the establishment of legal precedents But because activities in space have (until now) been limited in their scope and because states have generally refrained from filing complaints against each other, little to no legal precedents apply in space.[69]

OWNERSHIP AND SOVEREIGNTY RIGHTS ARE AMONG THE OST's MOST AMBIGUOUS SUBJECT AREAS

Perhaps more troubling, the OST is ambiguous on issues relating to sovereignty and property rights. The 1979 Moon Agreement – which was introduced with the goal of clearing up ambiguities relating to resource ownership in space, and stipulates that all non-Earth resources are "the common heritage of mankind" – was only signed by four countries. To this day, states disagree on several aspects of ownership of resources in space. Of most immediate relevance are disagreements pertaining to the right of private actors to lay claim to celestial bodies. The OST allows for the *extraction* of resources in space and disallows any form of national appropriation, but omits private sector actors entirely.[70] What happens when a dispute arises between Chinese and American mining corporations that have set up shop in close proximity on the lunar surface? Nobody knows.

ONLY FOUR COUNTRIES HAVE SIGNED THE MOON AGREEMENT

Picture 9 Starman: Elon Musk's Tesla roadster orbits Earth after being launched into space atop a Falcon Heavy rocket[71]

Taken together, these features offer public and private-sector actors alike incentives to engage in competition with the goal of establishing *faits accompli* which shape future legislation by their very existence.

Opportunities for the Netherlands

The knowledge, education, and innovation infrastructure that afford the Netherlands a strong position when it comes to contributing to the tackling of space debris, potentially also enable it to play a role in space exploration and exploitation's unfolding (preparatory) phase. Investments into space-related ventures have experienced a marked increase in funding in the previous years, with venture capitalists investing $5.8bn into 178 commercial space startups in 2019 – an increase of 38% over 2018.[72]

SPACE-BASED SOLAR PANELS, PROPULSION SYSTEMS, AND CLOSED-LOOP LIFE SUPPORT SYSTEMS ARE SET TO EXPERIENCE INCREASED DEMAND

As far as the funding for ventures relating to the exploration of outer space goes, the majority currently goes to companies focusing on the development of new launch systems. While the Royal Netherlands Aerospace Centre NLR has some expertise in this field,[73] the Dutch commercial sector is best positioned to take advantage of the investment phase which will follow the current one. The current wave of investments hopes to reduce the costs of launching objects into LEO – something that will increase the economic feasibility of assembling and maintaining something like a commercial research station. The following wave will focus on com-

SATELLITE TECHNOLOGIES WILL BE OF GREAT RELEVANCE IN THE RUN-UP TO 2050

panies with the ability to provide the modules being sent up with critical components. Many of the solutions that Dutch companies have developed within the context of satellite-related applications meet this criterion. The maintenance satellites, space-based commercial research hubs, and material-hauling spacecraft that will facilitate activities such as those outlined in United Launch Alliance's "Cislunar 1000" concept will need space-based solar panels, propulsion systems, closed-loop life support systems, and lightweight materials, among others.

Dutch companies are well-established as suppliers of space-based solar panels and propulsion systems. Airbus Defence and Space (formerly Dutch Space) developed the solar arrays fitted to ESA's Sentinel 1, Sentinel 2, and Envisat satellites, in addition to those fitted to NASA's Syngus and Dawn probes.[74] Aerospace Propulsion Products develops igniters for the Vinci and Vega rockets, as well as being involved in the development of new applications within ESA's Future Launchers Programme.[75]

Conclusion

Space security is important today and will develop into an ever more pressing issue in the decades to come. Incentivized by plummeting costs, public and private-sector actors are engaged in what in many aspects might become a "winner takes all" race – certainly in a world where multilateralism is under pressure. Fierce space competition carries significant political and military threats. Within the context and realizing the economic opportunities and mitigating the political and security threats of the use of space, the following policy recommendations are of relevance to Dutch policymakers.

THE NETHERLANDS ECONOMIC WELFARE AND MILITARY WARFIGHTING CAPACITY ARE EACH DEPENDENT ON SPACE COMPETITION NOT INTENSIFYING

Conduct an in-depth assessment of the Netherlands' dependence on space. Given its high level of global connectedness, the Netherlands is highly dependent on space-based infrastructure and services. Regardless, relatively little thought has been given to the possible impacts of large-scale disruptions of space infrastructure, either deliberately or by accident. There is a clear geopolitical angle to this consideration. In becoming reliant on satellites which are owned and operated by (mostly) American corporations or, in the case of the Armed Forces, by the US Military, the Dutch economic welfare and military warfighting capacity are subject to disruption as a result of initiatives to undermine American hegemony.[76] In order to develop policies and take steps to counter or mitigate such disruptions, the government should conduct in-depth studies to better understand the country's dependence on (foreign operated) space infrastructure. For the ministries of Foreign Affairs and Defense, such a study should explore the following:

- Assess the likely impact of space disruptions on the country's food stocks, critical infrastructure, and social stability.
- Establish which space-based services are of critical importance to the Netherlands and identify the satellite constellation(s) which they rely on.
- Integrate space-related concerns into diplomatic decision making. Learn to view military and political developments, at least partially, through the lens of Dutch space interests.
- Military developments, such as the potential nonrenewal of New START, potentially allow for the development of new ASAT weapons, increasing their relevance to the Netherlands. In a similar vein, states which test ASAT weapons are contributing to creation of space debris. In these instances, diplomatic options should be considered.
- Asses the Armed Forces' reliance on 3rd party-operated infrastructure.
- Invest in the creation of redundancies. One option for doing so is to launch a limited number of Dutch satellites into orbit with the goal of facilitating communications if a constellation such as the US-Milstar is disrupted.
- Formulate contingency plans. What are back-up forms of communications? Do F-35's return to base? What is the Netherlands' position on how NATO ought to respond?

Neither the Dutch Ministry of Defense nor the Dutch Ministry of Foreign Affairs have published space strategies. Defense touches on space in its *Defence Industry Strategy*,[77] but omits the domain from its most recent white paper.[78] Conducting such assessments will empower Dutch policymakers to take proactive measures aimed, on the one hand, at reducing the likelihood that the Netherlands will experience a "collateral" disruption, and at reducing the impact of such a disruption on the other.

Develop a Dutch policy on the secure exploitation of outer space. The Netherlands should develop a legal position on current gaps and ambiguities in the Outer Space Treaty. Developing such a legal framework will help to foster Dutch space-related industries over the course of the coming 20-30 years. It also serves to empower the country to contribute to the formulation of norms and rules pertaining to the space domain in the near future. This policy recommendation has the following implications for Dutch policymakers:

- Create an overview of ambiguities and lacunas in the OST. Identified issues should subsequently be ranged by their potential impact on Dutch economy and security.
- Formulate a Dutch policy which addresses these issues. Property and/or sovereignty rights, in addition to the existing formulation of the Liability Agreement, are likely to be of particular importance. The Netherlands and commercial actors alike are best served by an arrangement in which outer space is treated similarly to the open seas.
- Leiden University's International Institute of Air and Space Law and The Hague International Space Resources Governance Working Group constitute potential partners for drafting such a policy.

Explore, support, and expand the Dutch space industry. Current trends offer opportunities for Netherlands-based innovators to think about and develop solutions to space debris, produce nanosats, and find new markets for dual-use radar technologies within the context of Space Situational Awareness. As public and private sectors alike work towards the commercialization of space, there will also be increased demand for technologies relating to closed-loop life support, propulsion, and material extraction and refinement. On Dutch policymakers' part, this requires:

- Supporting initiatives to develop and apply new technologies within the context of new business models typically associated with startup initiatives.
- Within the context of this recommendation, consider companies which do not engage in space-related activities at the present time. To give an example, manufacturers of lightweight materials – and industry which is not traditionally space oriented – are likely to be well-positioned to attract business as the preparatory phase of space exploration continues to unfold. The Ministry of Economic Affairs' Netherlands Space Office (NSO) constitutes a prime candidate for spearheading such an initiative.[79]
- Ensuring these companies' ability to compete and to expand from startups to "growups" is likely to require some degree of government funding and support. Dutch companies will need track records to be able to compete internationally, meaning that initiatives should be made to include Dutch startups in consortia as subcontractors to parties such as the NLR or TNO.
- As is also the case with individuals with educations conducive to work in AI, brain drain to well-funded US companies such as SpaceX is likely to be of concern. The Netherlands' policy for building up its space ecosystem should strive to counteract this trend by supporting Dutch startups' efforts to retain domestic and to attract international talent.

The social stability, economic prosperity, and military warfighting capability of the Netherlands are all contingent on interstate competition *not* manifesting itself negatively in space. Because of this, developments associated with it warrant attention. More than 90 states have satellites in LEO, a host of powerful corporations have outlined plans to increase their presence in space, and the technologies necessary to exploit its vast resources are under active development. Even despite its small size, several attributes position the Netherlands well to play a role in mitigating the onset intensity and impact of such competition. As a middle-sized, entrepreneurial power with an advanced economy and a track record in championing legislative initiatives, the country can lobby for the adoption of rules on the world stage without being viewed as a "winner takes all" threat. The policy recommendations outlined in this section are explicitly geared towards building on and solidifying this legitimacy while also unlocking opportunities for the country's commercial sector.

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