Space Domain

Introduction to satellites and their military applications

Providence

Experience. Success. Together.

Table of Contents

Tables

Figures

Introduction

Space is now a battlespace, alongside Cyber, joining Sea, Land and Air. At the Association of Old Crows (AOC) annual conference in Adelaide last year, satellites emerged as a key debate topic, particularly regarding their vulnerability in Navigation Warfare (NAVWAR).

Providence has recently delved into the world of space, satellites, and their role in modern warfighting. This paper presents the findings of our research and aims to enhance understanding of satellites' role and the underlying technology, especially from a military perspective. It will include a focus on Australia and the role it plays within the 'Five Eyes' (FVEY) community and their role as part of the modern order of battle.

Since the successful launch of the Soviet's Sputnik-1 in 1957 and the United States' Apollo Space Program, which heavily involved each country's defence forces, nations have spent billions of dollars to find ways to exploit this frontier for defence purposes. This investment and research have led to the role of satellites specifically, and space more generally, moving from being enablers of the battlespace to critical components of it. Refer to Table-1 for key milestones in the evolution of satellite technology for military purposes up to the 1990s.

Date	Activity	Country
1957	Sputnik 1 launch	Soviet Union
1963	Invention of the Anti-Satellite (ASAT) capability	Soviet Union
1968	First satellite DFH-1 circumnavigates earth	China
1970	launched series of 33, Radar Ocean Reconnaissance Satellite (RORSAT),	Soviet Union
1971	Prospero was the only British satellite to be launched into space by a British vehicle was launched from the Woomera Rocket Range in Australia.	United Kingdom
1976	KH-11 (there were earlier variants) with a focus on electro-optical intelligence collection.	United States
1977	Launch (by NASA) of their Palapa series of satellites that were used for both public and defence purposes.	Indonesia
1980s	Star Wars program, principally an anti-nuclear missile platform discovered that satellites could be destroyed by specially designed missiles.	United States

Table 1 – Key Space milestones (Military Purposes) [1]

There are now 105 countries registered as satellite owners, as can be seen in Table 2. Compared to the top three satellite owners, Australia's involvement in satellite operations is relatively insignificant. When compared to all satellite owner countries, Australia is in the top 10 and has launched 49 satellites of which 32 are still active, which places it between Canada and Luxembourg (these details are listed in Appendix A).

Country	Number Launched
United States	4511
China	586
UK	561
Russia	177
Japan	90
European Space Agency (ESA)	62
Multinational	61
India	58
Canada	52
Australia	49
Luxembourg	45
Germany	44

Table 2 – Satellite Owners. [1]

We are poised for a period of high growth of satellite deployment, China alone has stated they planned to launch more than 290 in 2024. [1] The growth in satellites has been driven by three factors:

1) Accessibility to satellites underlying technology and as a platform, facilitated by space agencies making available payload space for third parties,
2) Improvement in satellite technology, and
3) Reduced size.

Figure 1 below shows how this evolution has had a significant impact with the price per kilogram of payload dropping from $US85,216 in 1981 to $US951 in 2020.

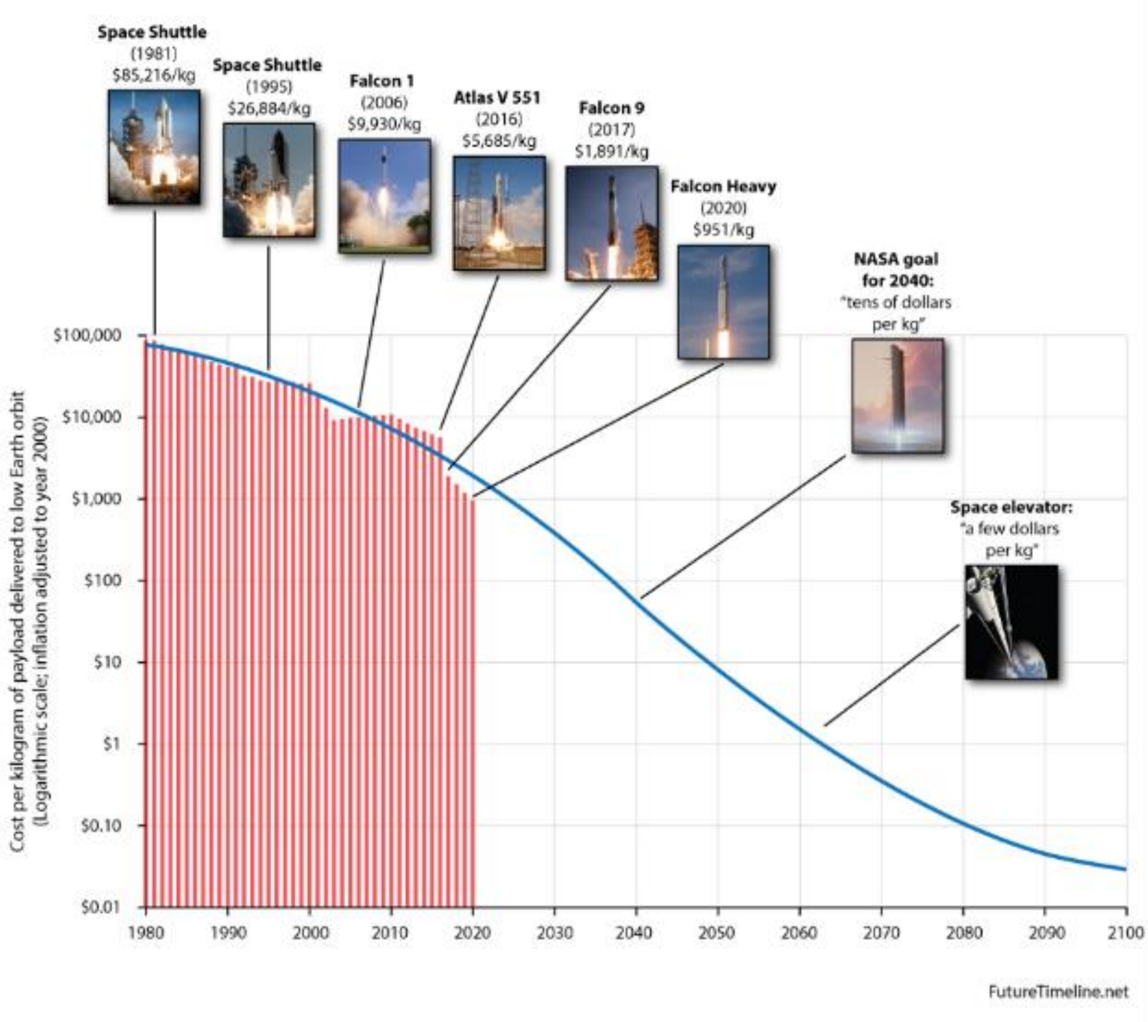

Figure 1 – Cost $US per kilogram of payload. [1]

Accessibility to satellite technology has led to an increased focus on this domain, from the formation of entire groups, such as the Space Force, to the building of capability in existing and new specialist units.

It has also led to an increased dependence on satellites by both civilian and military, principally communications, navigation, and intelligence collection. This has delivered significant efficiencies and insights. However, this dependence has concurrently exposed a vulnerability that foreign actors can exploit, both in kinetic and non-kinetic warfare.

What is Space?

Curiously, the actual definition of space is somewhat contentious, while Australia recognises space from the distance of 100km from the Earth's surface. [2] However, this definition is by no means universal. Figure-2 gives a graphical representation of space and its relationship to other elements of the Earth's atmosphere.

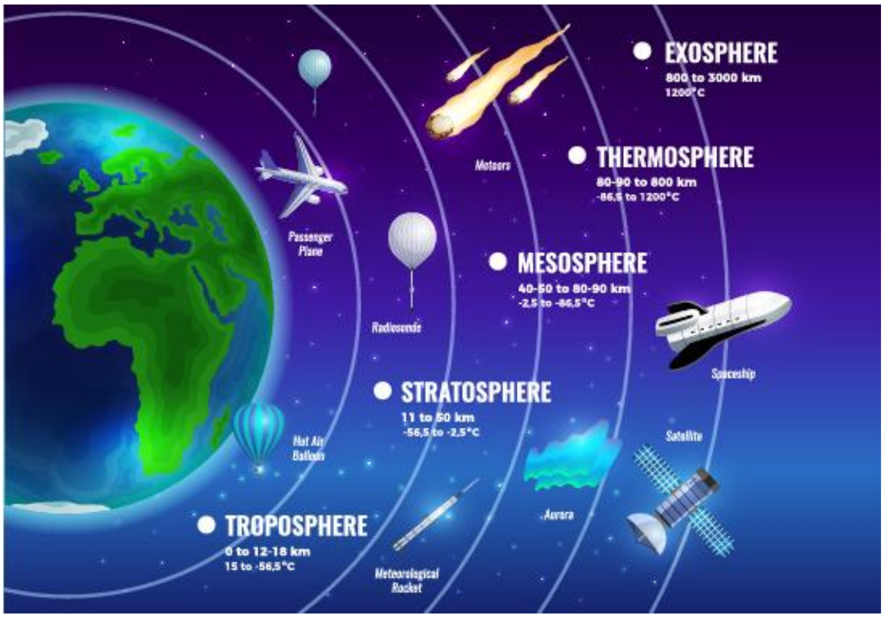

Figure 2 - Space - Physical Dimensions [2]

Within the space domain there are several distinct components, we will go into these in more detail in the respective sections of this report. Figure 3 gives an overview of the key elements and this will be an important building block to understanding space generally and satellites in more detail later in the report.

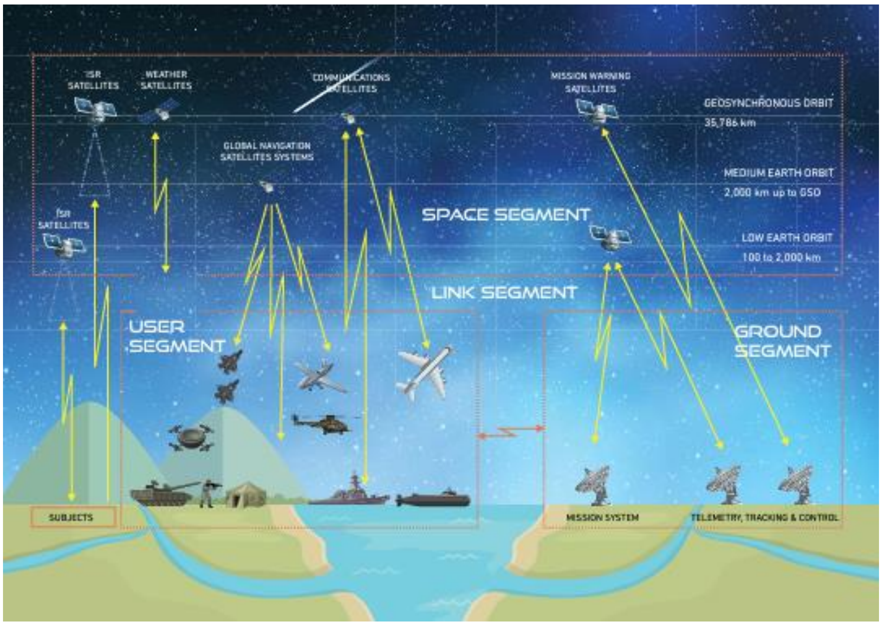

Figure 3 - Segments of Space Domain [2]

What is a Satellite?

Put simply satellites are human-made objects that orbit the Earth or other celestial bodies. There are 8261 satellites orbiting the earth, of which 4582 are active. [3] They come in assorted sizes and types, each designed for specific tasks. Satellites play a crucial role in not only defence, but they are now part of our everyday life, playing an integral role in a wide range of applications. Some satellites, like weather satellites, monitor Earth's atmospheric conditions to aid in weather forecasting. Others, like communication satellites, provide the infrastructure for many forms of global communication, including television broadcasts and internet services. Navigation satellites, such as those in the GPS network, provide precise timing and location data that are crucial for many applications, including navigation and emergency response.

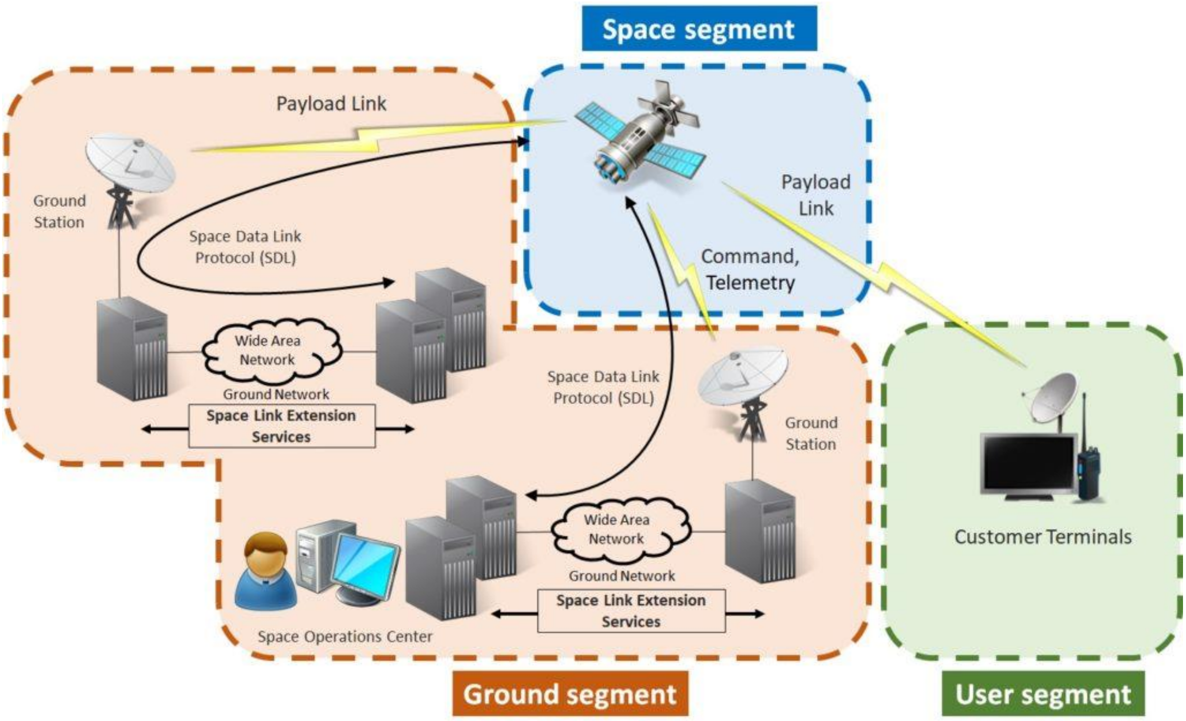

Figure 4 – Segments of satellite operations.

Every Satellite consists of three key elements:

- **Space Segment** – the actual object orbiting beyond the Earth's atmosphere.
- **Ground Segment** – the launch, operation, and maintenance of the satellite, typically by a series of earth stations and radio communications.
- **User Segment** – how the satellite is used to perform its desired function, for example a military satellite used for intelligence collection would be the transmission of intercepted communications or images to a processing facility, while a civilian satellite it might be the upload and download of television signals between regions of countries.

Beyond the simple explanation above, more details for the ground and user segments are beyond this paper's scope. However, to give a better understanding of the Satellite's role in defence context we will focus on the characteristics of the actual satellite's operation in the space segment.

While a very sophisticated piece of engineering, the shape of the satellite typically changes based upon its payload and tasking. However, all satellites have the following common components.

1. **Bus** – Guidance, Navigation and Control (GNCV), Antenna, Avionics and Power source.
2. **Payload** – Payload module will vary depending upon the satellites tasking, for some highly specialised satellites the payload is fully integrated into the satellite's form.

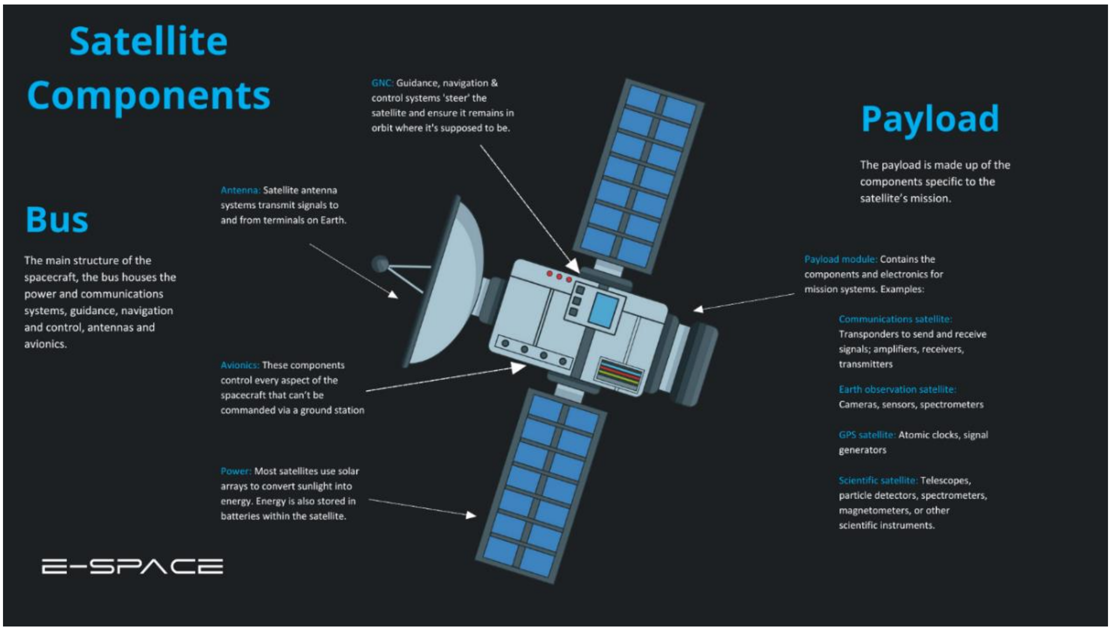

Figure 5 – Components of a satellite. [1]

How satellites operate and what do they do

Every satellite is defined by the following:

- **Orbit** – what type of orbit is it operating in?
- **Size** – what is the size is it? This determines the payload and size and therefore mission capability.
- **Function** – what task or tasks do they perform?
- **Frequency** – what frequencies does it transmit on, including operation and maintenance and the content for the function it performs?
- **Launch & Deployment** – What is the life cycle of a satellite?

Function

The principal classification is the satellite's intended function, determining its orbit and size. The seven common functions are summarised in Table -2 below and are the major determining factor of the satellite's orbit, size and transmission frequencies.

Type	Number	Description
Communications	3135	Transmit television and radio signals around the world. i.e. broadband and long-distance telephone calls.
Weather	1052	Monitor weather patterns and climate changes to provide meteorologists with the data necessary to predict weather forecasts and track severe storms.
Earth Observation	971 [4]	Observe the Earth's surface to gather information about its physical, chemical, and biological systems. They can monitor ocean and wind currents, measure the health of crops and forests.
Military	580 [5]	Defence and intelligence purposes. They can be used for reconnaissance, surveillance, communication, and navigation. Some military satellites are even capable of detecting missile launches or nuclear explosions.
Navigation	383	Backbone of navigation systems like the Global Positioning System (GPS). They transmit signals that are used by GPS receivers to determine their location on Earth with remarkable accuracy.
Space Science	154	Scientific research, such as studying the Earth's magnetosphere or observing distant celestial bodies. They have greatly contributed to our understanding of the universe.
Miniaturized	108	Advancements in technology have enabled satellites to become smaller and more cost-effective. These include CubeSats and nanosatellites, normally used for scientific research and technology demonstration.

Table 3 – Satellite Types [5]

The satellites available have evolved significantly over the last 50 years, with many of the classified aspects of military satellites evolving into everyday use. As technology continues to advance, the size, capabilities, access to and potential uses of satellites will only continue to grow.

Orbit

All satellites are designed to orbit Earth in one of seven paths as outlined in Table 3 below.

Each type of orbit has its advantages and disadvantages, and the choice of orbit depends on the specific mission requirements of the satellite. As technology advances, we may see new types of orbits being utilised for future satellite missions.
Refer to table 3 for specific information on each of these most common types of orbits, each serving unique functions that enhance our understanding of the universe and life on Earth. Understanding these orbits is crucial for leveraging satellite technology.

The trajectory paths of these orbits are illustrated in Figure – 6 below.

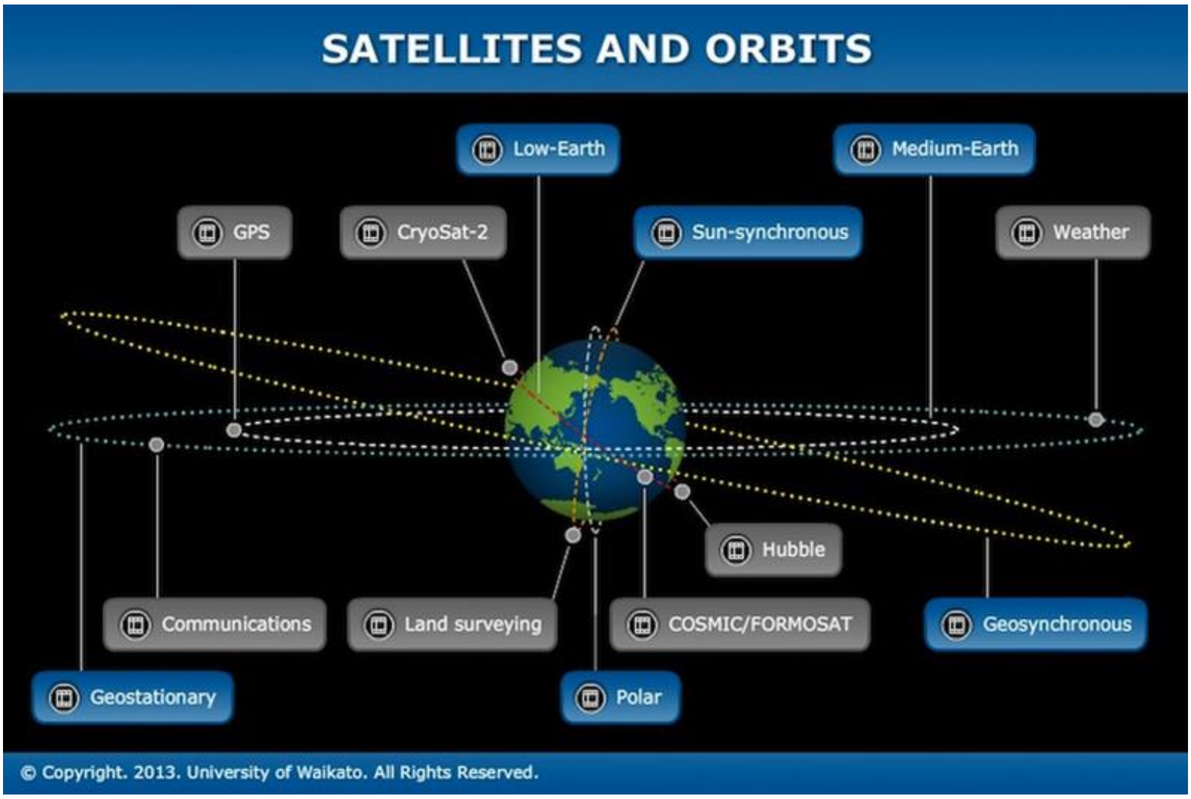

Figure 6 – Satellite orbit paths.

Orbit	Characteristics	Number (%)	Distance (km)	Speed (kmph)	Orbit (time)	Orbits (daily)	Latency (ms)	Typical Use	Example	Strengths	Weaknesses
Low Earth Orbit (LEO)	With altitudes ranging from 160 to 2,000 kilometers (about the distance from Florida to New York City), orbit Earth rapidly, completing revolutions in 90 to 120 minutes (about 2 hours), and their closeness to Earth allows for high-resolution imaging and data collection, ideal for reconnaissance and scientific research.	88%	160-2000	28,000	90-182 minutes	11+	10-50	- Communications - Earth imaging and survey - Military observation	- SpaceX Starlink - Hubble space telescope - International Space Station	- Cheap - Low Power - Lower Signal Latency	- Space Debris - Lower Lifespan - Atmospheric Drag
Medium Earth Orbit (MEO)	Positioned between LEO and GEO, typically at altitudes of 2,000 to 36,000 kilometers, are commonly used for navigation systems like GPS.	5%	2,000 - 35,786	11,300 – 28,000	2-24 hours	1-12	40-120	- Navigation - Communications - Remote sensing	- GPS - Galileo - GLONAS	- Efficient coverage - Lower latency than GEO - Optimal balance between LEO and GEO - High data transfer rates	- Launch cost - Radiation environment - Low signal strength
Geosynchronous Orbit	An orbit that matches the Earth's rotation on its axis, which takes one sidereal day (23 hours, 56 minutes, and 4 seconds). A satellite in a geosynchronous orbit appears to be in the same region in the sky at a given time of the day when viewed from a particular position on Earth. Geosynchronous satellites can have any inclination	N/A	35,786	11,300	23:56.4 hours	1	120	- Navigation - Communications - Space communications	- Astra 1 - MEASAT 2 - Raduga 29	- Efficient coverage (only 3 satellites cover Earth) - Global visibility from fixed point	- High communications latency - Limited polar reach - Low signal strength
Geostationary Orbit (GEO)	A special case of a geosynchronous orbit. It is a circular orbit located at an altitude of 35,786 kilometers (22,236 miles) above the surface of Earth with zero inclination to the equatorial plane. This means that a geostationary satellite always remains exactly above the Earth's equator. As a result, it appears to hover at a single point in the sky when observed from a given point on the ground.	9%	35,786	10,800	23:56.4 hours	1	240	- Communications (TV) - Intelligence collection	- Intelsat 18 - SES - Eutelsat	- Long life span - Continuous coverage over a fixed geographical area	- High communications latency - Lower resolution imagery compared to LEO & MEO
Polat Orbit (PO)	Fly in a path that takes them over the Earth's poles, allowing them to observe the entire planet over the course of several orbits.	N/A	700-1000	27,000	100 minutes	14.1	10-50	- Intelligence collection - Weather forecasting	- Iridium cluster - USAF DMSP surveillance - SPOT earth resources spacecraft	- Global coverage - High data resolution	- No continuous view of single location - Cannot leverage Earth's rotational velocity so larger launch vehicle required
Sun-Synchronous Orbit (SSO)&	Are placed in such a way that they pass over any given point of the Earth's surface at the same local solar time, making them useful for imaging, reconnaissance, and weather satellites.	N/A	600 - 800	27,000	90-120 minutes	14	10-50	- Earth observation – pass over the any given point at the same time - Weather forecasting - Intelligence collection	- MODIS - Cartosat-2A - NASA Landsat - PROBA-2	- Consistent illumination for imaging - Frequent revisit times - High-resolution imagery	- Limited continuous coverage - Orbital decay
Geostationary Transfer Orbit (GTO)	(aka Geosynchronous Transfer Orbit) – is a type of geocentric orbit. Highly elliptical It is used as an intermediate step for satellites destined for geosynchronous (GSO) or geostationary orbit (GEO).	N/A	Transit 160-2000 to 35,786	24,582	10.5 hours	2.3	10-240	- Transition from LEO to GEO - Communications	- Inmarsat fleet - EchoStar fleet - SpaceX SES-8	- Intermediate step - Staging benefits – fuel Payload capacity	- Orbital decay - Long transfer time - High energy requirement

Table 4 – Satellite Orbits [6] [7]

Size

Satellites come in a variety of sizes, each designed to fulfill specific functions and missions. The size of a satellite ranges from a small CubeSat that fits in the palm of your hand to a large communications satellite the size of a bus. There are six principal size categories of satellite, which along with examples of use are outlined in Table 5.

Size	Mass	Example	Notes
Large	>1000 kg	NASA LANDSAT Optus D3	High-capacity communications, high-resolution Earth observation, and deep space missions. Most capable type but the most expensive to build and launch.
Medium	500 – 1000 kg	Navstar 66	Communications, Earth observation, navigation, and scientific research. Larger and more capable than SmallSats, but still smaller, cheaper than traditional largeSats.
Small Satellites	100-500 kg	Starlink EOS SAT-1	Earth observation, communications, and scientific research. SmallSats are capable of hosting more complex payloads than MicroSats and cheaper than traditional.
Micro satellite	10-100 kg	Picard SMART-1	Earth observation, scientific research, and communications. MicroSats are larger and more capable than CubeSats and NanoSats, but still much smaller and cheaper than traditional satellites.
Nano satellites	1-10 kg	CENTAURI-3	Used for similar purposes as CubeSats, including scientific research and technology demonstration
Cube satellites	0.1 – 1 kg	I-INSPIRE II (AU03)	Scientific research, technology demonstration, and educational purposes. CubeSats are cost-effective and can be launched in groups, making them popular for universities and small companies.

Table 5 – Satellite Size [6]

In recent years, there has been a trend towards using constellations of small satellites to achieve the same capabilities as a single large satellite. This approach provides redundancy, flexibility, and the ability to upgrade the constellation by launching new satellites as technology advances.

Since the year 2000, small satellites accounted for 94% of all launches, with the Nano Satellite category the fastest growth in recent years. This has made satellite technology far more accessible than has been historically possible.

Frequencies

Satellites and ground stations use specific communication frequencies to ensure efficient and reliable data transmission. Different frequencies are used for uplink and downlink to avoid interference, with higher bandwidths allowing for faster data transmission. The radio frequencies are shared with terrestrial radio services, necessitating international frequency assignment to prevent interference. Ground stations, positioned strategically worldwide, provide additional reliability by connecting to at least two satellites. This intricate system is designed for high-speed, dependable communication.

The typical bands considered for satellite communication are:

Band	Frequency	Notes
L-band	**1 to 2 GHz**	used for mobile communication, such as satellite phones and Global Positioning System (GPS) signals.1
S-band	**2 to 4 GHz**	used for weather radar, surface ship radar, and some communications satellites, especially those used by NASA to communicate with the International Space Station.
C-band	**4 to 8 GHz**	used for long-distance satellite telecommunications.
X-band	**8 to 12 GHz**	used for military communications and weather monitoring.
Ku-band	**12 to 18 GHz**	used for satellite communications, particularly for fixed and broadcast services.
Ka-band	**26.5 to 40 GHz**	used for high-speed satellite broadband services.
V-band	**40 to 75 GHz**	used for high-capacity satellites.

Table 6 – Satellite Transmission Frequencies

The choice of frequency band is determined by several factors, including the purpose of the satellite, the required data rate, the size and cost of the ground antennas, and the regulatory constraints. The

International Telecommunications Union (ITU) is the global body that assigns radio frequency allocations to avoid interference between all the different uses made of the radio spectrum.

Launch and Deployment

The process of launching and deploying military satellites is a complex and meticulously planned operation. Here's a step-by-step overview of how it typically happens:

Design and Development	Pre-Launch Preparations	Launch	Deployment	In-Orbit Operations	End of Life
The first step involves designing and developing the satellite based on its intended purpose, whether it's for communication, surveillance, navigation, or other military applications. This process can take several years and involves rigorous testing to ensure the satellite can withstand the harsh conditions of space.	Once the satellite is built, it's prepared for launch. This involves mounting the satellite onto a launch vehicle, which is a rocket designed to carry payloads into space. The satellite is housed within the launch vehicle's payload fairing, a protective shell that shields the satellite during its journey through the Earth's atmosphere.	The launch vehicle, carrying the satellite, is launched from a spaceport. The rocket ascends into space, jettisoning lower stages as their fuel is depleted. The exact trajectory and speed depend on the intended orbit of the satellite.	Once the launch vehicle reaches the desired orbit, the satellite is deployed. The payload fairing is jettisoned, and the satellite is released into space. This is a critical phase of the mission, as the satellite must be placed into the correct orbit with precision.	After deployment, the satellite unfolds its solar panels and antennas. It then undergoes a series of checks to ensure all systems are functioning correctly. Once operational, the satellite can start its mission, whether it's capturing images, relaying communications, or performing other tasks.	At the end of its operational life, a satellite is decommissioned. This usually involves moving the satellite to a 'graveyard' orbit where it won't pose a risk to other operational satellites, or de-orbiting the satellite so it will burn up in the Earth's atmosphere

Table 7 – Satellite Lifecycle [5]

Throughout this entire process, mission control teams on the ground closely monitor each step. They track the launch vehicle during ascent, oversee the deployment of the satellite, and then manage the satellite's operations while it is in orbit.

It is important to note that the specifics of launching and deploying military satellites often remain classified due to national security reasons. However, the general process is like that of civilian satellites. As technology advances, new methods such as reusable rockets and satellite constellations are being developed, which could revolutionise how military satellites are launched and deployed in the future.

Governance of Space

The use of space and satellites is governed by a complex framework of international and national laws and treaties. These legal instruments aim to promote the peaceful use of space, prevent the militarisation of space, and ensure equitable access to space resources [4] [5] [6]. Key organisations involved in shaping these regulations include the Space Foundation, the Australian Communications and Media Authority (ACMA) and the UN Office for Outer Space Affairs

International

Space is viewed as part of the heritage of mankind, which means everyone has equal access to it. Over the last 50 years the governance of space has evolved via five space treaties: [6]

- The outer space treaty – referred to as the constitutional magna carta for space – 1967 -intention to keep nuclear weapons away from the space domain.
- The liability convention
- The rescue and return agreement
- The registration convention

- The Moon agreement

The Outer Space Treaty

The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, commonly known as the Outer Space Treaty, is the foundational legal instrument governing the use of space. Adopted by the United Nations General Assembly in 1966 and entered into force in 1967 [11], the treaty establishes several key principles:

1. Peaceful Purposes – The treaty stipulates that space shall be used exclusively for peaceful purposes. It prohibits the placement of nuclear weapons or any other weapons of mass destruction in space.
2. Freedom of Exploration and Use – The treaty establishes the freedom of all states to explore and use space. It stipulates that space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.
3. Responsibility and Liability – The treaty holds states responsible for their activities in space and liable for any damage caused by their space objects.
4. International Cooperation – The treaty encourages international cooperation in the exploration and use of space, for the benefit and in the interests of all countries. [4]

The Registration Convention

The Convention on Registration of Objects Launched into Outer Space, commonly known as the Registration Convention, is another important legal instrument governing the use of space. Adopted by the United Nations General Assembly in 1974 and entered into force in 1976, the convention requires states to maintain a registry of objects launched into space and to provide information on these objects to the United Nations. [6]

The ITU Radio Regulations

The International Telecommunication Union (ITU) Radio Regulations govern the use of the radiofrequency spectrum and satellite orbits. These regulations aim to prevent harmful interference between different satellite systems and ensure equitable access to the spectrum and orbits. [6]

Other Legal Instruments

In addition to these treaties and regulations, there are several other legal instruments that govern specific aspects of the use of space and satellites. These include the Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space, which provides for the rescue and return of astronauts in distress and the return of space objects; and the Convention on International Liability for Damage Caused by Space Objects, which establishes rules for determining liability for damage caused by space objects.

The international legal framework governing the use of space and satellites is complex and evolving. It seeks to balance the interests of different states, promote the peaceful use of space, and ensure the sustainability of space activities. As space use grows and new challenges emerge, it will be crucial to continue developing and strengthening this legal framework. [6]

National

Australia's satellite operations are comprehensively managed and regulated. The Australian Space Agency (ASA), a government body, supervises the country's space activities, and Australia is a founding member of the United Nations Committee on the Peaceful Uses of Outer Space. [4]

The Space (Launches and Returns) Act 2018 governs civil space-related activities conducted from Australia, to Australia, or by Australians abroad. This Act aims to balance the encouragement of participation and innovation in the space industry with the safety of space activities and the minimization of damage risk to persons or property.

Australia adheres to all five United Nations space treaties, which establish the international legal framework for space activities. The Radiocommunications Act 1992 mandates that all radiocommunications devices' operation, including Earth stations and space stations on satellites, be authorised by a license issued by the Australian Communications and Media Authority (ACMA).

Under the Space (Launches and Returns) Act 2018, there are three legislative instruments that set out the rules: the General Rules, the High-Power Rocket Rules, and the Insurance Rules. These rules provide clear information and a streamlined process for approving an activity under the Act.

Australia is committed to ensuring a safe, stable and sustainable outer space environment by fostering a culture of safety and sustainability within the Australian space sector. The Space Regulation Advisory Collective (SRAC), a network of non-government space sector representatives and other interested parties, informs the regulatory function of the Australian Space Agency.

Australia's Role in Satellites

Australia's own involvement in satellites began with the launch of the scientific WRESAT-1 in 1967, followed by other scientific and amateur launches. Interest grew significantly with the launch of the Palapa series of satellites by near neighbour Indonesia and has continued to grow with subsequent launches. The most significant development in Australia was their adoption of communications satellites that began with Aussat-1/2/3, all launched between 1985-87.

Date	Notes
1957	Australia agreed to host two tracking stations at Woomera Rocket Range, South Australia, to support the US Vanguard satellite program. This was the beginning of space tracking in Australia, which is Australia's longest continuous space activity1.
1964-1970	The European Launcher Development Organisation (ELDO) was a predecessor of the European Space Agency (ESA). Australia provided launch facilities at Woomera and also became an ELDO member. There were ten ELDO test flights from Woomera between 1964 and 19701.
1967	Australia's first satellites were launched in 1967 and 1970. WRESAT-1 (WRE Satellite) was developed by the Weapons Research Establishment (WRE), which managed the Woomera Range, and the University of Adelaide. WRESAT was launched from Woomera on 29 November 1967, using a rocket donated by the US. The flight made Australia one of the earliest nations to launch its own satellite1 and WRESAT-1 completed 642 orbits
1985-87	Australia's first domestic communications satellite Aussat-1/2/3
1986	The Australian Space Board and the first National Space Program were established to support the development of an Australian space industry.
1987	The Australian Space Office was established and Aussat 3 was launched.
1988	The first Ausroc 1 student rocket was launched by the Australian Space Research Institute.
2018	The Australian Space Agency was established1.
2018	NASA chose a remote area in Australia's north to carry out its first-ever commercial rocket launch outside the United States. This demonstrated Australia's expertise in managing remote operations and complex facilities2.
2023	Space Industry Responsive Intelligent Thermal (SpIRIT) satellite was launched from Vandenberg Space Force Base in California, USA, and was a Nano Satellite
2022 - 24	Canberra-based Skykraft and Airservices Australia are launching a constellation of 200 satellites over two years to improve flight safety and communication
2023	NASA partnered with Australia for the Artemis mission to return astronauts to the Moon and then travel to Mars, with an Australian-made rover to play a key role in the lunar expedition2
2023	The project to build Australia's own satellite launch facilities achieved significant milestones. Negotiating began on Indigenous land use agreements, environmental analysis was undertaken and development approvals were received3.
2024	The Optimus satellite was created by Sydney-based Space Machines Company and launched from California aboard a SpaceX Falcon 9 rocket. It is designed to repair and refuel other space infrastructure and will also test state-of-the-art printed solar cells developed by the CSIRO Optimus

2024	Skykraft in collaboration with Airservices Australia, plans to launch a constellation of 200 satellites over the next two years to improve flight safety and communication.
2024	Optus, in collaboration with SpaceX, plans to roll out SMS from late 2024, with voice and data also on the horizon from late 2025. This will be achieved through a phased rollout of SpaceX's satellite capability.
2025	Gilmour Space is preparing to launch Australia's first locally made orbital rocket, the Eris, from a small north Queensland town. The company has received approval from the Australian Space Agency. [7] [Please note that these plans are subject to change and for the most accurate and up-to-date information, it's best to check with official announcements or news from the respective companies or the Australian Space Agency.]

Table 8 – Australian Satellite Key Milestones. [1] [2]

The involvement in space operations by Australia has been evolving rapidly, Fig 7 below illustrates this steady growth of launches from an average of 0.5 in the 2000's, 1.4 on the 2010's to 5.25 thus far in the 2020's.

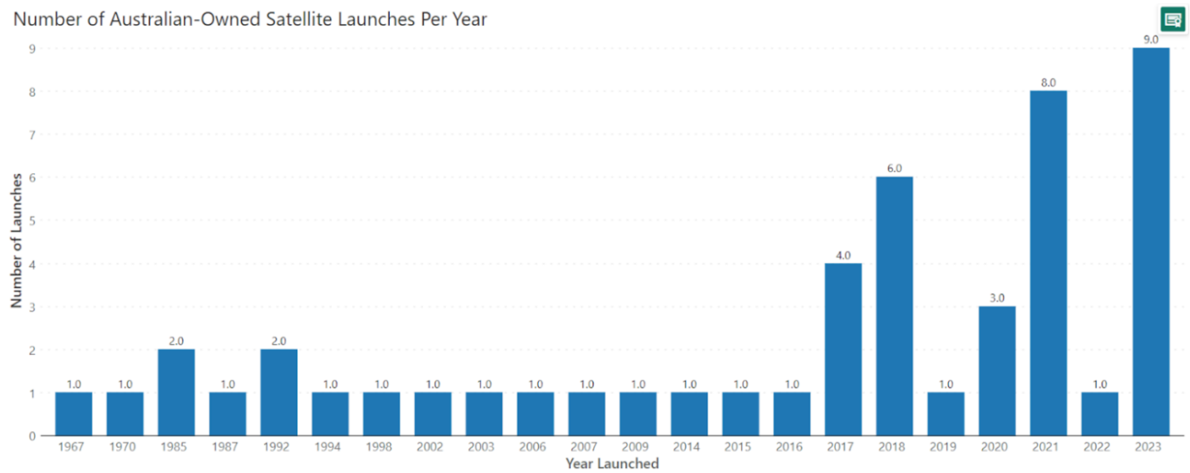

Figure 7 – Australian Satellite Launches (by year). [1] [2]

The launch of Australian satellites that began with Australia's pioneering Woomera Rocket Range in 1967 with the launch of WER1 saw no other satellite launches for the next 60 years. As outlined in Figure 8 below.

Figure 8 – Australian Satellite Launches (by location). [1] [2]

Australia has launched 49 (35 commercial) satellites in total and 32 (27 commercial) are still active, 11 are decayed and 6 are currently inactive. The orbit type of active satellites are 25 (78.13%) LEO and 7 (21.88%) GEO. The larger commercial, government and defence satellites typically have a life span of 15 years. Commercial operators have also extended their satellite lifetimes by using robotic vehicles. Optus exemplifies this with plans to extend its D3 satellite lifetime (which was launched in 2003) using SpaceLogistics Mission Robotic Vehicle and Mission Extension Pod (Harrison, 2022). This would augment the satellite's existing propulsion system, giving it up to six years of extra life (Harrison, 2022).

Since the establishment of the Australian Space Agency in 2018 Australia has taken strides to return to its position it held as one of the pioneers. Australia's direct involvement includes NASA's Moon to Mars exploration program known as Artemis and involves specific responsibility for the Trailblazer Program. This will see the design and development of an Australian-made rover that goes to the Moon with NASA, as part of its Artemis program [8].

To contribute to the development of a sovereign space supply chain, the Agency awarded over $9 million in grants to 12 new space projects on 1 March 2024, aligned to NASA's Artemis program. This innovation will also benefit and build credentials within the global space industry [9]. International organisations are also investing into the Australian space industry, as demonstrated by Italian based Leonardo with their investment in Black Sky Aerospace [10]. These initiatives are contributing to a surge in the Australian space industry. IBISWorld estimates that by 2020, the Australian space sector had grown to $5.7 billion, comprising over 800 businesses and supporting more than 15,000 jobs. [10]. Key companies who have grown to support this sector and their contribution are outlined in Table 9.

Company	Product / Service
Gilmour Space Technology	Building its Eris expendable booster
Hypersonix Launch Systems	Developing a fully reusable hypersonic spaceplane called Delta-Velos
Fleet Space	A South Australian-based nanosatellite company
Regrow	An Agri-tech company that uses satellite data to guide farming practices
Southern Launch	Developing Australia's fist local launch pad
Black Sky Aerospace	Manufacturer of solid rocket fuel, motors, launch vehicles
SkyKraft	Have already launched 5 of the proposed 200 satellites into LEO to deliver global air traffic system that can provide aircraft coverage even in remote areas.

Table 9 – Sovereign Space Sector.

Australia is ideally suited for sovereign space launch, giving it a key role in augmenting and, if necessary, reconstituting space support in a crisis. There has been a particular focus on the development of sovereign launch capabilities. The status is outlined in Table 10.

Location	State	Operator
Nhulunbuy near Gove in the	Northern Territory	Equatorial Launch Australia
Whaler's Way near Port Lincoln	South Australia	Southern Launch
Abbott Point Bowen	Queensland	Gilmour Space Technologies
Wellcamp airport Toowoomba	Queensland	Virgin Orbit

Table 10 – Sovereign Launch Capability. [1] [2]

At the time of writing, Gilmour Space is preparing to launch Australia's first locally made orbital rocket, the Eris, from a small north Queensland town. Having received permission from the area's traditional owners, the company has now received launch approval from the Australian Space Agency for an early 2025 launch. [16]

Satellites in Military Operations

The military and national security application of satellites builds on many of the civilian uses and involves additional capabilities aligned to the highly specialised nature of their operations. In this section I will outline the key principle military uses and include a couple of case studies to assist with the understanding of their application.

From an Australian military perspective, after the initial involvement with the launches at the Woomera Rocket Range, their exploitation of space has taken three paths, it is use for communications, it is used for ISR collection purposes and the direct interception of foreign powers satellite communications. These will be dealt with in more detail below.

Satellites play a crucial role in various military operations, providing capabilities that are vital for national security. There has been steady growth in the number of satellites and countries using them. The top 10 are detailed in Table – 11 below. Note that because of the necessary secrecy about the military use of satellites, accurate figures are difficult to locate from unclassified sources. Additionally, there is significant obfuscation regarding the function of satellite payload. Many satellites are used both civilian and military purposes, examples include (IMARSAT / OPTUS etc.)

Country	Number Launched
USA	239
China	140
Russia	105
France	18
Italy	13
Israel	11
India	9
Germany	7
United Kingdom	6
Spain	6

Table 11 – Military Satellites Top 10 Countries [15]

In addition to the civilian applications outlined previously, there are four five military applications of satellites within the space domain; Communication, Intelligence, Surveillance and Reconnaissance (ISR), Missile Warning, meteorology and positioning, navigation, and timing (PNT). An overview of how satellites contribute to military operations is outlined in Table-12 below.

Application	Notes
Communication	Communication satellites are a key component of modern military operations. They provide secure, reliable, and instantaneous communication links between different units and command centers, regardless of their location on the globe. This allows for effective coordination and execution of operations. In addition, communication satellites enable the transmission of enormous amounts of data, including real-time video, which can be crucial for decision-making in the battlefield.
Intelligence, Surveillance and Reconnaissance (ISR)	Surveillance satellites are used to monitor activities around the world. They can provide detailed imagery of potential areas of interest, helping to identify military installations, troop movements, and other relevant information. Reconnaissance satellites, on the other hand, are used for more targeted observations, often using high-resolution sensors to gather detailed intelligence about specific targets. These satellites can operate day and night, and in all weather conditions, providing a continuous source of valuable information.
Missile Warning	Space-based missile warning can detect and track missile activity across the globe. [17] High-resolution and Infra-Red space based sensors can provide global and theatre based missile warning alert capabilities, against ballistic and non-ballistic missiles (e.g. hypersonic, glide, cruise). Depending on the type of missile, flight stage (e.g. launch, boost, mid-course and terminal) and weather conditions (e.g. cloudy), they can detect the launch and direction of incoming missile threats with high accuracy and precision, including the predicted impact zone, to provide warning time for commanders, air defence operators and deployed forces.
Meteorology	Weather satellites provide critical information about atmospheric conditions, which can significantly impact military operations. Accurate weather forecasts can influence the planning and execution of

	operations, from determining the best time for an air strike to predicting the movement of enemy troops based on weather conditions. In addition, weather satellites can provide information about the space weather, which can affect the operation of other satellites and communication systems.
Position, Navigation and Timing (PNT)	Navigation satellites, such as those in the Global Positioning System (GPS), provide accurate positioning and timing information. This is crucial for a variety of military applications, including guiding missiles to their targets, synchronizing operations across different units, and enabling soldiers to navigate in unfamiliar terrain. The accuracy and global coverage provided by navigation satellites have revolutionized military operations, making them an indispensable tool for modern militaries.

Table 12 – Satellite Military Uses [5]

Communications (SATCOM)

Satellites play a crucial role in military operations in the realm of communication. They provide secure, reliable and instantaneous communication links between different units and command centers, regardless of their location on the globe. Australia's use of SATCOM has evolved from ad hoc communications in the early 1980s where it relied on the use of other countries SATCOM network, including the use of bandwidth on existing commercial satellites, to leveraging bandwidth dedicated to defence with the launch of OPTUSXX satellite, to partnering with the US and Canada on the Wideband Global SATCOM System (WGS). The latter phase of the evolution is covered in the case study below.

Case Study – Wideband Global SATCOM System

The Wideband Global SATCOM (WGS) system is a high-capacity satellite communications system delivered by a constellation of 10 satellites in geostationary orbit, providing high-speed broadband used by the United States Department of Defense (DoD), Canadian Department of National Defence (DND), and the Australian Department of Defence [11].

A team led by Boeing Integrated Defence Systems was awarded a contract to develop the WGS system in 2001. The contract was worth $160.3 million and was extendible up to $1.3 billion [12]. Boeing's team agreed to supply the satellites, spacecraft, and payload control equipment under the deal, as well as logistics, training, and sustained engineering support[12].

The WGS-1, the first satellite of the WGS system, was launched into orbit on October 10, 2007, on the United Launch Alliance (ULA) Atlas V launch vehicle [11]. According to a quote on Spaceflight Now, "A single WGS spacecraft has as much bandwidth as the entire existing DSCS constellation."[11]. It delivers this by integrating the Defence Satellite Communications System (DSCS) satellites and the Global Broadcast System (GBS) operating at an ultra-high frequency (UHF)[12]. This delivers two-way X- and Ka-band communications, as well as Ka-band broadcast services to the US armed forces and other allied forces worldwide, and X-band satellite transfers of data, photos, and videos to troops on the battlefield[12].

Australia plays a significant role in the Wideband Global SATCOM (WGS) system[13]. In 2007, under Joint Project 2008 Phase 4, Australia signed a cooperative agreement with the US Air Force, becoming the first international participant in the WGS system [14] [15]. Under this agreement, Australia funded WGS-6 the sixth of 10 satellites plus associated ground infrastructure, including the Satellite Ground Station West (SGS-W) near Geraldton in Western Australia, at a cost of $927 million[14] [15]. This arrangement gives Australia access to a proportion of the power and bandwidth across the entire constellation until 2029, providing the Australian Defence Force (ADF) with a global voice, data, and video communications capability in the X and Ka frequency bands. [14]

Australia's contribution to the WGS system has not only enhanced its own military communication capabilities but also strengthened its alliance with the United States and other international partners and demonstrates Australia's commitment to contributing to global security and defence efforts.

This case study highlights the evolution of SATCOM and the importance of satellite communications in modern military operations. They not only enable effective coordination and execution of operations, but also provide a means for continuous monitoring and situational awareness.

Case Study – Australia's Defence Satellite Communications System

Australian Defence Force (ADF) relies heavily on satellites for long-range communications. In a recent announcement, Head of Air Defence and Space Systems Division, Air Vice-Marshal David Scheul, said that "Currently across Defence there are up to 89 capabilities which depend on satellite communications." [16]. This demand for bandwidth, increasing geopolitical tensions and the age of the existing WGS system means Australia needs to develop their own sovereign SATCOM system.

The Australian Government announced in November 2024 that it will consider multi-orbit satellites, in line with the US approach, after cancelling the single orbit GEO-based satellite communications system that was being procured under Tranche 1 of Joint Project 9102. [17] Chief of Joint Capabilities Lieutenant General Susan Coyle said about the cancelled procurement for a GEO-based satellite communications system, "This was phase one with the GEO level. We determined that that wouldn't be adequate and that we needed to have multi-orbital approach sooner," citing the need for greater resiliency in operating in the current strategic and threat environment.

Intelligence, Surveillance and Reconnaissance (ISR)

Use of satellites for ISR collection is one of the most highly classified and speculated upon aspects of the space domain, which makes it a challenge to provide extensive, corroborated details on this set of capabilities.

However, understanding their role in space and asymmetric warfare is crucial. Recently declassified documents from the US's National Reconnaissance Office (NRO), responsible for deployment of satellite technology, and the National Security Agency (NSA), which processes collected information, offer insights into past satellite capabilities. By piecing together these documents and other publicly available information, we can build a picture of current potential uses. To simplify what is one of the most complex areas of defence and national security, I will divide ISR into two, observation (S&R) and interception (SIGINT).

Surveillance and Reconnaissance – designed specifically for imaging Earth's surface at high resolution from space, it provides detailed images and video of potential targets on the ground. This real-time surveillance provides valuable insights into patterns and trends that may not be visible through other means. United States Intelligence Community relies on anywhere between 339 to 485 military or government satellites which provide Geospatial Intelligence (GEOINT), Measurement and Signature Intelligence (MASINT) collections. [18] [19] [20] [21]

Signal Intelligence (SIGINT) – Some military satellites are equipped to intercept and analyse foreign electronic emissions, such as radar (ELINT) and radio communications (COMINT). This can provide valuable intelligence about the capabilities, activities, and intentions of potential adversaries. The US operates an estimated 49 satellites dedicated to SIGINT collection, composed of the ORION and ADVANCED networks. [20] [18] [21]

It has been possible via unclassified sources to build a picture of the evolution of satellites used for ISR functions since the launch of the Soviet Sputnik satellite in 1957.

Date	Satellite	Purpose	Milestone
Pre-Sputnik Era (1956)			Development of the first cameras specifically designed to photograph and track U.S. scientific satellites.
Post-Sputnik Era			The development of the Space Detection and Tracking System (SPADATS) to keep up with the increasing number of space objects, especially Soviet military satellites. The U.S. began developing SIGINT satellites to monitor Soviet communications and missile tests during the Cold War.
1959	KH-1 (Key Hole)	Imaging	The first attempted launch of a known intel satellite by the US and the start of the Orion program. This launch attempt was unsuccessful. [22]
1960	GRAB	SIGINT	Galactic Radiation and Background was the first satellite to return data, in this case ELINT on Soviet radars.
1965			A high-level working group was established to review the entire U.S. space surveillance program.
1963	KH-7 Gambit	Imaging	It was the first US satellite to return hi-resolution images with a resolution of 2 feet, providing crucial intelligence during the height of the Cold War.
1970	RHYOLITE (aka Aquacade)	SIGINT	launch of the geosynchronous satellite program, which allowed continuous coverage of missile telemetry and targets in Eurasia.
1971	KH-9 Hexagon (aka Big Bird)	Imaging	The launch of the first successful photo reconnaissance satellite. It contributed to the SALT treaty negotiations and had a resolution down to 1 foot. The first satellite, which provided broad area search capability. It returned film back to earth for processing via recoverable capsules. [23]
1976	KH-11 Kennan	Imaging	The launch of the first satellites, which provided real-time imagery via secure communications links. [24]
1978	Navstar 1	Navigation	The first in a constellation of PNT satellites that for the global GPS network
1980s	Lacrosse (aka Onyx)	Imaging	The first radar imaging satellites, which could see through clouds and at night.
	Chalet (aka Vortex)	SIGINT	The intercepted SIGINT data is believed to have been fed into and analysed by the National Security Agency ECHELON system. [23]
1980s	Orion Jumpseat (x2)	SIGINT	Development and deployment of advanced SIGINT satellites with improved capabilities for intercepting and processing signals
1980s	Zircom	SIGINT	The United Kingdom's first intelligence satellite was scheduled to be launched by the NASA space shuttle in 1988. However, it was cancelled in 1987 due to funding issues.
1990s	USA-53 (Misty)	Imaging	The launch of the first generation of the Future Imagery Architecture satellites this series alone cost an estimated $US 15.3 billion adjusted for inflation in 2023 prices.
1990s	Advanced Orion Trumpet (aka Jeroboam)	SIGINT	The integration of SIGINT satellites with other intelligence systems, enhancing the ability to process and disseminate information.
2000s	QuickBird	Imaging	The launch of the first commercial high-resolution imaging satellites, by DigitalGlobe which provided additional capabilities to the intelligence community. [25]
2000s	Advanced Orion (Series 4-6)	SIGINT	Modern SIGINT satellites with sophisticated technologies for high-frequency, VHF, and UHF signal interception.
2010	USA-215	Imaging	First of the Future Imagery Architecture (FIA)1 satellites who used synthetic aperture radar (SAR) [26]
2023	USA-345 (Mentor 9)	SIGINT	SIGINT satellites launched by the US. [27]
2024	NROL-70	SIGINT	Believed to be a new generation of SIGINT satellites destined for GEO orbit. [25]
2024	USSF-124	SIGINT / Imaging	A series of 6 missile defence satellites launched by the Missile Defence Agency. [28]
2024		SIGINT / Imaging	U.S. Department of Defense announced an ambitious plan to launch 1,000 satellites over the next decade.
2024 -2026	ISTARI	SIGINT / Imaging	The UK's multi satellite intelligence gathering network is scheduled for launch with Tyche planned for summer 2024, followed by Tatiana and Oberon in 2025 and Juno in 2026. [29]

Table 13 – FVEY ISR Satellite key milestones [27] [28] [29]

Case Study (Surveillance) – Iran's Imam Khomeini Space Center Explosion

On the 30th of August 2019, then US President Donald Trump tweeted a photograph from an NRO surveillance satellite of what was one of a series of explosions at Iran's Imam, Khomeini Space Centre. Research by amateur satellite trackers suggests the path taken for the photograph is likely to be USA 224 launched in early 2011 [30] and one of the NRO's KH-11 Evolved Enhanced Crystal satellite. [31] The KH-11 series was first launched on 19th December 1976 under the code name Kennen and later evolved to the present code name. Interestingly, they were also the first satellites able to transmit their images back to Earth via a network of COMSATS known as the Satellite Data System (SDS) network. [32] Previous generations had to rely on their images transferred physically on film back to the Earth for processing. [33] The photograph pictured in Figure 9 reveals a charred launchpad at the Imam Khomeini Space Center in Iran, which had just experienced its third launch failure of the year. [34]

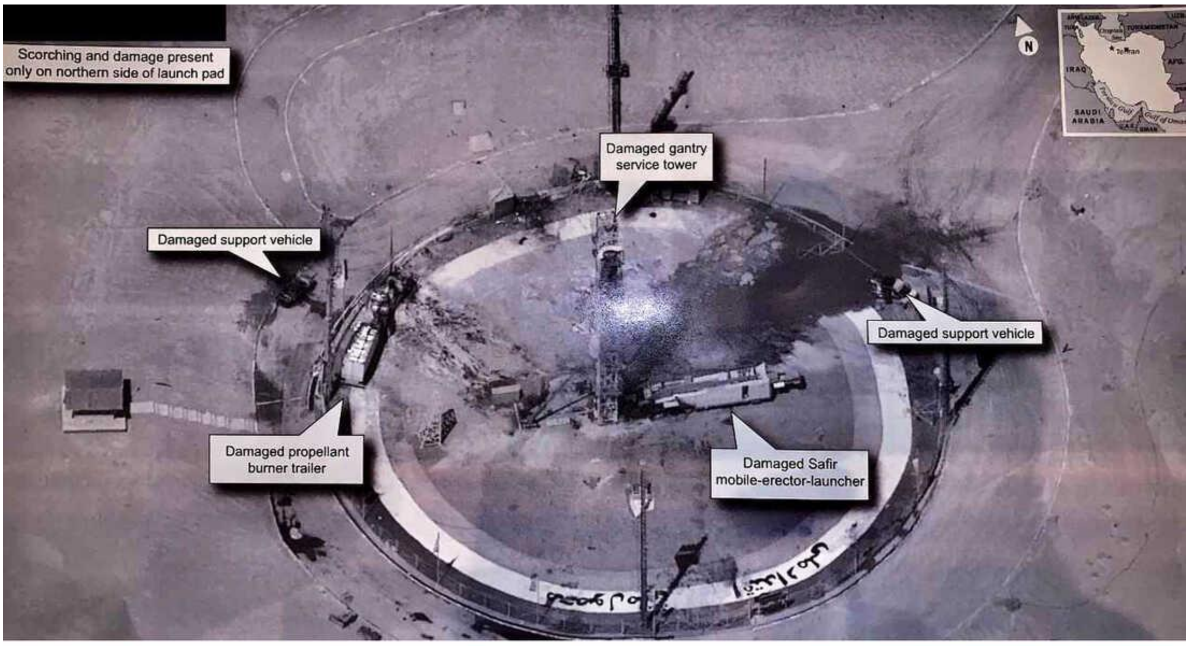

Figure 9 – Declassified reconnaissance image vs commercial image [42]

This photograph is instructive for several reasons, it is only the second time in over 50 years that a photograph has been shared with the only redaction being the security classification, most likely to protect sensitivities around the compartmented codeword. The other interesting fact is that the image does not seem to have been obfuscated in any way to project the technology capability of the satellite. This has enabled us to compare the surveillance image from what is believed to be KH-11 satellites outfitted with a 2.4-meter mirror, which could snap photos with a resolution of about 10 centimetres (about the length of the long edge of a credit card).

Satellite company Planet Commercial picture at the highest-resolution commercial imaging satellites can reach roughly 25 centimetres. The contrast in capability is staggering, particularly when you consider that the satellite was launched in 2011. [30] Refer to Figure 10 to see how these satellites have evolved since 1961. [35]

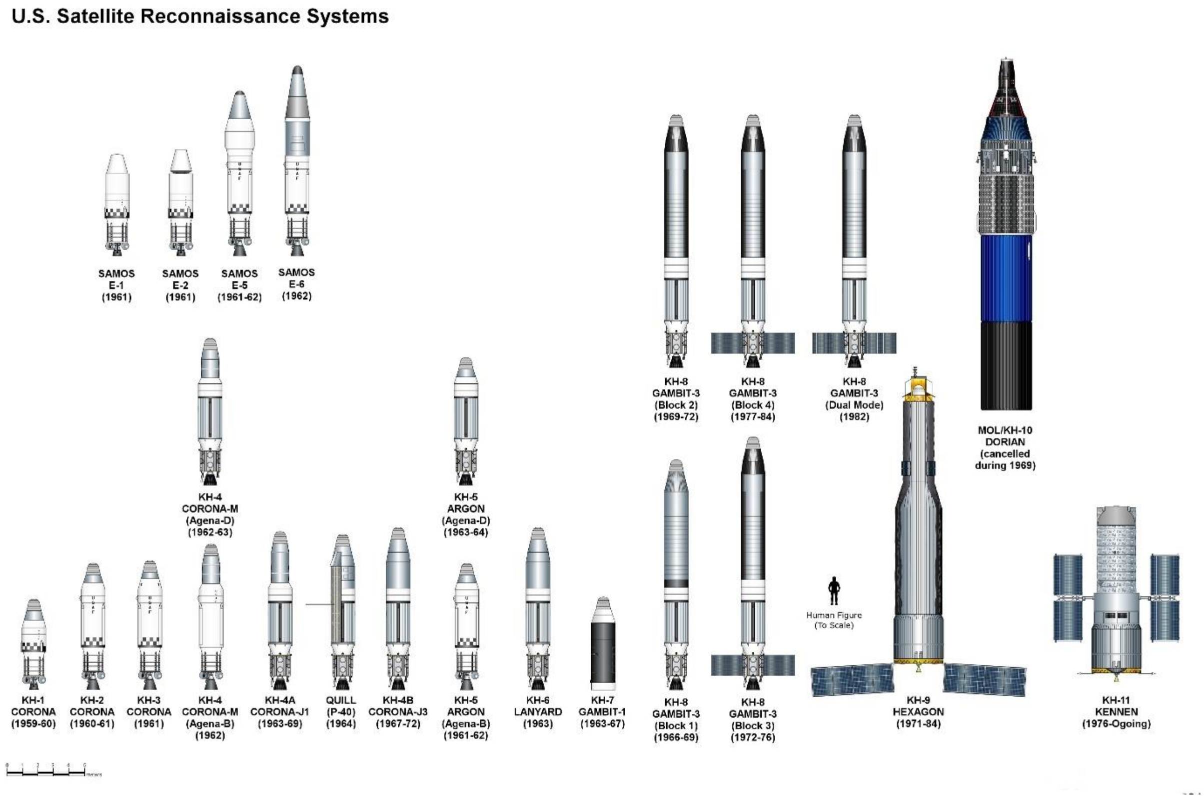

Figure 10 – Evolution of US Reconnaissance Satellites [43]

Case Study (SIGINT) – Terrorist Internet Café Location

These satellites are used to support several programs, nearly all have remained either classified or are the basis of speculation without any credible use cases, except for one. The web journal The Intercept disclosed that one such SIGINT capability was GHOSTHUNTER a program that enabled persons of interest to be targeted as soon as they logged into their internet café.

A 2009 document added that GHOSTHUNTER's focus was at that time "on geolocation of internet cafés in the Middle East/North Africa region in support of U.S. military operations," and said that it had to date "successfully geolocated over 5,000 VSAT terminals in Iraq, Afghanistan, Syria, Lebanon, and Iran." VSAT, or Very Small Aperture Terminal, is a satellite system commonly used by internet cafés and foreign governments in the Middle East to send and receive communications and data.

GHOSTHUNTER could also call home in on VSATs in Pakistan, Somalia, Algeria, the Philippines, Mali, Kenya, and Sudan, the documents indicate. [36] In 2007 the intercept alleges, GHOSTHUNTER was used to identify an alleged al Qaeda 'weapons procurer' in Iraq named Abu Sayf. The NSA's surveillance systems spotted Sayf logging into Yahoo email or messenger accounts at an internet cafe near a mosque in Anah, a town on the Euphrates River that is about 200 miles northwest of Baghdad. [36] This information was passed to U.S. military commanders based in Fallujah to be included as part of a 'targeting plan'. [36]

A few days later, a special operations unit named Task Force-16 stormed two properties, where they detained Sayf, his father, two brothers, and five associates. [36] In a leaked report it was alleged that at least 30 terrorists were eliminated, many after the intelligence was used to task the MQ-9 Reaper drone, leading to the elimination of the threat. [36]

Case study (SIGINT) – Orion Satellites

The Orion satellites, also known as Mentor or Advanced Orion, are a class of United States spy satellites developed by the National Reconnaissance Office (NRO) and operated by the National Security Agency (NSA). [37] These satellites collect signals intelligence (SIGINT) from space via the interception and analysis of foreign electronic emissions, such as radar and radio communications. This can provide valuable intelligence about the capabilities, activities, and intentions of potential adversaries. The satellites are equipped with large (estimated 100 metre diameter) radio reflecting dishes and are believed to target telemetry, VHF radio, cellular mobile phones, paging signals and mobile data links. [20] [37]

For instance, the NROL-44, a SIGINT satellite, and part of the Orion series, is one of the biggest. It weighs more than five tons and has a huge parabolic antenna which unfolds to a diameter of more than 100 metres in space. It is used to 'hoover up' hundreds of thousands of cell phone calls or scour the dark web for terrorist activity. [19] [20]

These satellites play a crucial role in the U.S. government's intelligence gathering efforts, providing a wealth of information that can be used for strategic decision-making. [37]

Meteorology (MET)

Earth observation satellites play a crucial role in Australian meteorology, providing essential data for weather forecasting, natural disaster response and climate science.

Case Study (MET) – National Space Mission for Earth Observation (NSMEO)

The Australian Government has announced the NSMEO program to design, construct, launch, and operate four new Earth observation satellites. These satellites will be central to the lives of everyday Australians – from forecasting the weather and responding to natural disasters, to managing the environment and supporting farmers. [38] [39]

Position, Navigation and Timing (PNT)

The role and importance of satellites in PNT has become increasingly critical due to the increased use of drones and other unmanned technologies, which has resulted in an exponential growth in the use of PNT information.

Case Study (PNT) – Global Positioning System (GPS)

The Australian Defence Force has access to a range of global and regional satellite navigation systems. However, its principal source is the US operated Global Positioning System (GPS).

Australian Defence Force (ADF) uses the Global Positioning System (GPS) for positioning, navigation, and timing. [40] The GPS system has been available since 1973 and consists of a constellation of 24 satellites. [40] The (GPS) provides two levels of service; the Standard Positioning Service (SPS) and the Precise Positioning Service (PPS). [41]

Standard Positioning Service (SPS) – This is available free worldwide for general civilian use. The SPS signal is not as accurate as the PPS signal. SPS can only pinpoint an object within 100 meters (the length of two Olympic swimming pools). [41]

Precise Positioning Service (PPS) – This is primarily intended for use by the US Department of Defense and selected allies. The PPS signal is scrambled to prevent enemies from targeting it. PPS pinpoints the location of an object to within 90 centimetres (about the length of a cricket bat). [41]

However, with the increased threat of NAVWAR and GPS jamming equipment, which has become easier to produce and deploy. The Australian Government Department of Defence is undertaking an upgrade via a project, known as JP5408 Phase 3 (Platforms) Tranche 2, which will enhance GPS on a range of ADF platforms by providing either protection or redundancy capabilities in response to GPS denial activities. [42] This development is but one of the projects being undertaken globally by defence and national security agencies to harden the PNT capabilities.

Threats to Military Satellites

The security vulnerability of satellites is particularly alarming. Researchers, nation-states, and even ordinary cybercriminals have long demonstrated how to hijack the control and communications aspects of satellite technology or destroy them outright.

In a recent paper *Space Odyssey: An Experimental Software Security Analysis of Satellites* [43] a survey of 19 engineers and developers representing 17 different satellite models. Of those 17, three respondents admitted they had not implemented any measures to prevent third-party intrusion. In five cases, the respondents were unsure or declined to comment, while the remaining nine had, implemented cyber defence. Yet the efficacy of some of these remedial measures are questionable — with only five of those nine having implemented any kind of access controls. This highlights a significant threat, even from a unsophisticated bad actor.

Military satellites occupying the Space battlespace are facing an ever-increasing number of threats. These threats are divided into two categories, Non-Kinetic and Kinetic. [44] [45] [46]

Kinetic – includes attacks resulting in physical damage to the satellites. Examples include missiles, rockets, lasers and other forms of destructive power such as lasers and collisions.

Non-kinetic – includes various attacks that do not result in physical damage to satellites. Typical applications include cyber and electronic attacks. This is akin to traditional warfare.

In combination, this means there are literally dozens of kinetic and non-kinetic effects that can be used to impact the role of satellites in modern warfare. Adversaries can use their own space capabilities to enhance their military forces and prepare for potential conflicts. [44]

These threats are constantly evolving and nations must continually update their defensive measures to protect their space assets. [45]

Kinetic

There are two broad categories of kinetic effects that can be used against satellites:

- **Physical Attacks** – These involve the use of anti-satellite weapons (ASATs) to physically damage or destroy satellites. [44] [45] [47]
- **Space Debris** – Accidental collisions with space debris can damage or destroy satellites. [44]

Physical Attacks

The principal method of physical attack is an anti-satellite missile launched into space by ballistic missiles, aircraft, drones of other satellites. This technology by the US's Project Bold Orion was developed shortly after the Soviets launched the Sputnik 1 in 1957. [47]

The US quickly followed as part of Operation Fishbowl, which involved the detonation of a 1.4 megaton nuclear warhead 250 miles above the earth, which also generated an electromagnetic pulse (EMP) seriously damaging electronic systems in Hawaii over 9,000 miles away, demonstrating the potential for EMP damage in space. [48]

Since then, it has been something of an arms race to develop the strongest capabilities. The Soviets responded with a co-orbital that was able to fly beside the target satellite and detonate to destroy the target satellite. The Chinese entered the fray when they blew up one of their redundant weather satellites with a ballistic missile in 2007 generating 3,000 trackable pieces of debris – known as 'space junk'. [47] India tested their own ASAT capabilities with project Mission Shatki in 2019. [49]

The most recent ASAT test is believed to be in 2021 when the International Space Station (ISS) observed a dangerously close satellite explosion believed to be caused by a Russian ASAT missile test. It was noteworthy that the ISS includes a Russian section operated by its own cosmonauts. It also placed at risk the Chinese space station Tiangong and its crew of taikonauts. [50]

With the evolution of next-generation kinetic weapons, including hypersonic missiles, rail guns, and lasers, the latter two reliant on the electromagnetic spectrum (EMS) to eliminate the risks associated with explosive ordnance or flammable propellants. These attributes make them highly suitable as ASAT weapons, deployable by conventional means or as part of a satellite's own defense and attack capabilities. One such example is the Russian Avanguard hypersonic glide vehicle, which can carry a nuclear or conventional warhead, and even if fired without its 2-megaton nuclear warhead the impact of the conventionally armed missile travelling at up to Mach 20 would still generate an explosive force of 21 tons of TNT and would obliterate any object in its path. [51] [52]

Another possibility of an attack on a satellite is leveraging existing vehicles that are used to grab debris to grab a complete satellite and remove it from space. This capability was demonstrated by a Chinese spacecraft in 2022, involving a SJ-21 grabbing a decommissioned satellite and throwing it away into a 'graveyard' orbit, raising concerns that it could do similar to US satellites during conflict. [53] This capability is being developed by a Japanese company, which in 2024 manoevered their spacecraft to a rendezvous point close a discarded rocket in Earth's orbit. The mission was performed by the satellite technology company Astroscale, who intend to eventually remove the 36-foot-long spent rocket stage, which makes up one of the 27,000 pieces of space junk (objects larger than 10 centimetres in orbit). This capability could of course eventually be militarised to enabled the military to move enemy spacecraft out into the 'graveyard' orbit and take it out of the conflict. [54]

Any future global conflict is likely to be preceded by a pre-emptive attack in the space domain, this could significantly impair any asynchronous advantage a party would have from the space domain. It would be akin to the 21st century equivalent of Pearl Harbor. Such attacks are only likely to be countered by the effective deployment of advanced AI capability, space warfare capabilities and intelligence collection.

Space Debris

Theres an ever-present threat from space debris, whether intended or not, to all satellites. The NASA scientist Donald Kessler best defined this in 1978, known as the Kessler Effect. He demonstrated that a 1cm object orbiting in space has the same kinetic energy as a hand grenade. [55]

Any form of kinetic effect that causes space debris generates a significant risk of collateral damage to their own satellites.

The growth of space debris is becoming a significant problem, particularly when ASAT capabilities are tested without any effort to not only clean it up buttake responsibility for its monitoring. This was the case with the Indian test Mission Shield, which generated 400 pieces of debris without having any capability to monitor the result. [49] China and the US have demonstrated similar ASAT missile capabilities, along with Russia whose ASAT test from 2021 blew up their satellite into 1,500 pieces. [56]

The notion of space debris brings a significant opportunity to deploy it as a kinetic effect, while raising the question was it intentional or accidental. It also raises the issue of survivability of LEO satellites during conflict, whereby any Kinetic attack would then create space debris that could damage satellites in low orbit – a space domain equivalent of the nuclear deterrence concept of Mutually Assured Destruction. The threat of attack against satellites in low orbit emphases the need for deploying multi-orbit satellites to help ensure a level of survivability and service during conflict.

Non-Kinetic

- **Tracking, Monitoring and capturing –** Adversaries can track and monitor satellites and their transmissions, potentially gaining valuable information about military operations. [44]
- **Electronic Attacks –** These include jamming and spoofing attacks that interfere with the signals transmitted by the satellites. [44] [45]
- **Cyber Attacks –** Satellites and their ground stations can be targeted by cyber-attacks, which can disrupt their operation or even take control of the satellites. [45]

Tracking, Monitoring and Capturing

The tracking of satellites for both defence and civilian purposes is conducted via several programs and generally falls under the rubric of Space Domain Awareness (SDA). The US Space Force defines SDA as encompassing the effective identification, characterisation and understanding of any factor associated with the space domain that could affect space operations and thereby impact the security, safety, economy or environment of a country. Space situational awareness (SSA) is a subset of SDA, providing awareness and object intelligence in the physical domain of space. [57] SSA is used to performed conjunction assessment, a key capability that uses the space object data to identify the risk of two objects colliding in space and alert operators. These alerts enable commercial operators and governments to work together and help the satellite operator move its satellite to a new 'slot' and avoid collision and a potential international incident. What is required to perform conjunction assessments is historical data identifying every object in orbit, along with regular observations for what object has moved or is behaving differently, in addition to artificial intelligence to perform autonomous monitoring and issue alerts so that the operators and warfighters have near-real time investigative capabilities to assess the risk of collision and take action.

Data, data libraries and analytics

Data are central to being able to identify and monitor space objects and provide real time situational awareness in an increasingly congested, contested and competitive operational domain. Bluestaq won a $280 million contract from the US Space Force in 2021 to develop a cloud-based data repository known as the Unified Data Library, or UDL, in which data can be stored and accessed by the warfighter to enable real time data based decision making. [58] To help unlock the power of big data, KBR's developed the Iron Stallion (IS) solution, which is a Multi-Domain Awareness platform that is operated by the US, UK and Australia. Cloud based, it uses suite of web applications focused on data integration, operator and machine workflow and automated data analytics and draws on:

- more than one million raw sensor observations
- 10 million total space data records
- more than 1.5 million air and ship tracks per day from 1,800 sensors, and
- data from 20 concurrent real-time commercial and government space providers. [59]

Seen as a core part of the key solutions for providing SDA to the Australian Defence Forces, Iron Stallion is now being used by Australia's Joint Capabilities Group's Space Command (SPACECOMD) to find, watch, track and report on the movement of objects in space. [60] SPACECOMD understands the importance of buying in data from various suppliers to form a Minimum Viable Capability and avoid vendor lock in, and is actively buying space data on the Global Marketplace database, [61] which is a neutral broker whereby government, businesses and citizens can buy unclassified space data that is sourced from radar observation and Electro-Optical observations, for all orbital regimes. [62]

Monitoring, capturing and countering

A Russian inspector satellite, known as Luch 2, was reported by space tracking firm Slingshot Aerospace on 27 June 2024 to have been positioning itself near several communications satellites in what appears to be an ongoing signals intelligence-gathering mission. [63] Luna 2 has a reported history of 'sniffing' communications satellites European, African and the US in an attempt to obtain key data on communication frequencies, capabilities and payload. Slingshot previously stated that Luna 2 has space tracking software that operates as a "machine learning-based object profiling engine" and pulls data from multiple sources. In terms of countering communication satellites, Russia claims to have developed a 'Starlink Killer'. [64] Named Kalinka, the Eurasian Times reported on 14 December 2024 that Russia's new system can counter the SpaceX's Starlink signals from the LEO network, which has proven crucial for Ukraine, particularly in directing aerial and sea drones to strike key Russian targets. The Kalinka system is claimed to be able to locate, identify and disrupt the Starlink signals from fixed and mobile Starlink communications nodes and is planned to be rolled out across Russian air, sea and land platforms.

Ground Segment

Interestingly, the surveillance of space from ground stations is also an area of high priority, an example is Australia's Defence Science and Technology Group (DSTG) has developed a satellite spectrum monitoring system called Cortex. Operating as a constant 'eye in the sky', Cortex detects any anomalies in the system and provides operators with enhanced situational awareness of what is happening across the network. [19] There's also the United State Space Surveillance Network (USSSN) which is capable of detecting, tracking, cataloguing and identifing artificial objects orbiting Earth, such as active/inactive satellites, spent rocket bodies, or fragmentation debris. [66]

Monitoring of satellites has been an integral toll in the SIGINT toolbox since the first COMSAT was launched. In fact Australia under Project Larswood is reported to have been monitoring Indonesia SATCOM since 1979, initially targeting their Palapa satellites from their Shoal Bay Receiving Station base located northeast of Darwin in the Northern Territory. [67] More recently, the FVEY MOONPENNY program is reported to intercept communications between foreign satellites. It was estimated that it tracked 163 such signals in real-time. In a single 12-hour period in May 2011, for instance, its surveillance systems logged more than 335 million metadata records, which reveal information such as the sender and recipient of an email, or the phone numbers someone called and at what time. [36]

Electronic Attacks

Electronic attacks have been developed over several years and unlike kinetic attacks, are widely accessible to most nations. The key forms of electronic attacks include jamming by using electronic signals to overpower the satellite's own signals, preventing it from manoeuvring and communicating with other parties. Spoofing by transmitting false signals to satellites to disrupt its operations. There is also a lot of research into areas of high-powered lasers and high-powered microwaves. In this instance, their application is not designed to make the satellite explode, but rather to blind the satellite by 'dazzling' the optical sensors with laser light, as Russia is reportedly developing. [68] Other methods include:

- Orbital Jamming – a beam of contradictory signals directed towards a satellite, which then mixes and overrides legitimate signals and blocks their transmission.
- Terrestrial jamming – rogue frequencies directed to ground-based targets, such as consumer-level satellite dishes, distorting their transmission.
- Hijacking – the unauthorised use of a satellite for transmission or seizing control of a signal, such as a broadcast and replacing it with another.
- Scanning – a process for identifying, attacking, and stealing information from a targeted host.

The Russians are acknowledged as having some of the most advanced capabilities in this area. [69] There has been a trend of public disclosure of such attacks, with recent incidents including the deliberate jamming of GPS signals in Norway and Finland during NATO exercises. [77] Recent conflicts in Syria and Ukraine have seen the use of jamming both reconnaissance and communications satellites. [69]

Cyber Attacks

Cyber threats to satellite systems originate from a wide range of sources, spanning from independent hackers with basic technology to state actors' offensive cyber security teams backed by billion-dollar technology investments.Unfortunately, most satellite operators, civilians and military have been complacent about the security of their satellite networks, in space and their ground stations. As a result, significant funds have been invested in cyberwarfare, particularly targeting satellites. Developing capabilities in this area can be quite cost-effective, providing a substantial asymmetric advantage. Russia, China, Iran, and North Korea have been developing sophisticated anti satellite soft kill capabilities. Some of their activities have been undertaken by third parties, which increases deniability and attribution. As a result, the US Director of National Intelligence has called space out as one of the critical threats to the "new global frontier" US DNI in 2019.

In 2021, to demonstrate how easy it was to hack a satellite, James Pavur PhD student at Oxford University where he researchers satellite cyber security, [70] used 300 pounds of commonly available satellite television equipment. He was able to hack a satellite and obtain sensitive data including AMEX credit card data, passwords from Fortune 500 companies, including global financial institutions.

Just last year, on the day of its ground invasion, Russian hackers caused an outage for the Ukrainian satellite Internet service provider Viasat. [71] And on Nov. 18, 2023, pro-Russian hacktivist group Killnet performed a distributed denial-of-service (DDoS) attack against SpaceX's Starlink system, which was providing connectivity to cut-off regions of Ukraine. Fortunately, their limited access to advanced offensive cyber capabilities meant this attached was contained. [72]

In retaliation for the death of their founder, the Wagner Group caused a temporary outage at Russian Internet provider Dozor-Teleport one of their largest, who provide critical communications infrastructure to organisation such as Gazprom and the Russian military. This was achieved by attacking numerous satellite ground terminals by uploading malware. This was particularly alarming as ground terminals were previously considered more secure than attacking the satellites directly via their typically wide-open communications link. [73]

The above activities confirm that the capability of hacking satellites has spread beyond defence and national security agencies to the hacker community. In a recent search conducted by the author on the dark web, 1789 results were delivered with links to algorithms and code to support such activities.

In September 2023, a well-known Russian hacking forum, offered [74] for sale a Maxar Technologies satellite that they had ambushed – they have a constellation of satellites providing high resolution imaging to corporate and governments, including the US National Geo-spacial intelligence agency. Most of the imagery from reporting from the war in Ukraine comes from their satellites. In 2022, they signed a US 3.2 billion deal to provide imaging to the National Reconnaissance Office (NRO) and also provide mobile terminals to access their satellites. [22]

Russia states these private sector satellites, including Starlink in Ukraine, are now a legitimate target. Russia has also successfully hacked satellites, crippling the US company Viasat's C2ISR by using AcidRain; a wiper malware targeting Viasat modems and routers. This attacked and erased all data on the system and when rebooted the hardware was permanently disabled, destroying thousands of terminals [MIT Technology Review]. [75]

Protection and Defensive Measures

Measures taken to protect military satellites from potential threats can include physical protection measures, cybersecurity measures and more. Military organisations employ a variety of strategies to mitigate threats to their satellites: [76] [77] [78]

- **Resilient Architectures** – design their satellite systems to be resilient, such as redundancy to remove single points of failure and withstand attacks and continue to function. [76] . The US Airforce hack-a-sat competition allows hackers to expose flaws in their satellite systems. [76]

- **Space Domain Awareness** – They monitor space closely to detect potential threats as early as possible. [76] This includes tracking space debris and monitoring the activities of other countries in space. [76]
- **Cybersecurity Measures** – They employ robust cybersecurity measures to protect their satellites and ground stations from cyber-attacks. This includes using encryption, firewalls, intrusion detection systems and other security technologies. [78]
- **Physical Protection** – In some cases, they may use military force to protect their satellites. [77] This could involve deploying anti-satellite weapons to deter or counter attacks. [77]
- **International Cooperation** – They work with allies and international organisations to promote responsible behaviour in space and discourage attacks on satellites. [79]
- **Threat Information Sharing** – They share threat information with private sector partners, such as the dissemination of critical space domain awareness and cybersecurity threat information at multiple classification levels. [77]

The application of these strategies and the circumstances in which they're used is outlined in Table 14.

Effect Type	Threat	Details	Countermeasures	Details
Kinetic	Physical Attacks	Anti-satellite weapons (ASATs) to physically damage or destroy satellites. [44] [45]	1. Resilient Architectures 2. Space Domain Awareness 3. Defensive Measures	1. Satellites are designed to be resilient, meaning they can withstand attacks and continue to function. This can involve using redundant systems, so if one satellite is disabled, others can take over its functions. [44] 2. Military organisations monitor space closely to detect potential threats as early as possible. [44] 3. NAVWAR defensive measures seek to prevent adversarial electronic warfare countermeasures from interfering with operational use of GPS in two ways—developing a new military signal (M-code) and developing new receivers that can utilise M-code and incorporate improved antijam and anti-spoofing technology. [46]
Kinetic	Space Debris	Accidental collisions with space debris can damage or destroy satellites. [44]	1. Resilient Architectures 2. Space Domain Awareness 3. Defensive Measures 4. Active Debris Removal (ADR)	1. Satellites are designed to be resilient, meaning they can withstand attacks and continue to function. This can involve using redundant systems, so if one satellite is disabled, others can take over its functions. [44] 2. Military organizations monitor space closely to detect potential threats as early as possible. This includes tracking space debris and monitoring the activities of other countries in space. [44] 3. NAVWAR defensive measures seek to prevent adversarial electronic warfare countermeasures from interfering with operational use of GPS in two ways—developing a new military signal (M-code) and developing new receivers that can utilize M-code and incorporate improved antijam and anti-spoofing technology. [46] 4. Some organizations are researching and developing technologies to actively remove space debris from orbit.
Non-Kinetic	Tracking and Monitoring	Adversaries can track and monitor satellites and their transmissions, potentially gaining valuable information about military operations. [44]	1. Resilient Architectures 2. Space Domain Awareness 3. Defensive Measures	1. Satellites are designed to be resilient, meaning they can withstand attacks and continue to function. This can involve using redundant systems, so if one satellite is disabled, others can take over its functions. [44] 2. Military organizations monitor space closely to detect potential threats as early as possible. This includes tracking space debris and monitoring the activities of other countries in space. [44] 3. NAVWAR defensive measures seek to prevent adversarial electronic warfare countermeasures from interfering with operational use of GPS in two ways—developing a new military signal (M-code) and developing new receivers that can utilise M-code and incorporate improved antijam and anti-spoofing technology. [46]
Non-Kinetic	Electronic Attacks	These include jamming and spoofing attacks that interfere with the signals transmitted by the satellites. [44] [45]	1. Resilient Architectures 2. Space Domain Awareness 3. Defensive Measures 4. Intrusion Detection and Prevention 5. Supply Chain Risk Management	1. Satellites are designed to be resilient, meaning they can withstand attacks and continue to function. This can involve using redundant systems, so if one satellite is disabled, others can take over its functions. [44] 2. Military organizations monitor space closely to detect potential threats as early as possible. This includes tracking space debris and monitoring the activities of other countries in space. [44] 3. NAVWAR defensive measures seek to prevent adversarial electronic warfare countermeasures from interfering with operational use of GPS in two ways—developing a new military signal (M-code) and developing new receivers that can utilize M-code and incorporate improved antijam and anti-spoofing technology. [46] 4. By leveraging signatures and machine-learning, cyber intrusions can be detected and blocked as craft payloads. 5. A program to protect against malware inserted into parts and modules.
Non-Kinetic	Cyber Attacks	Satellites and their ground stations can be targeted by cyber-attacks, which can disrupt their operation or even take control of the satellites. [45]	1. Resilient Architectures 2. Supply Chain Risk Management 3. Secure Communication Protocols and Encryption: 4. Intrusion Detection and Prevention	1. Satellites are designed to be resilient, meaning they can withstand attacks and continue to function. This can involve using redundant systems, so if one satellite is disabled, others can take over its functions. [44] 2. A program to protect against malware inserted into parts and modules. 3. Establishing secure communication protocols and implementing end-to-end encryption for data transmission are fundamental countermeasures. This ensures that even if data is intercepted, it cannot be understood. 4. By leveraging signatures and machine-learning, cyber intrusions can be detected and blocked as craft payloads. This helps to identify and respond to threats in real time.
Non-Kinetic	Force Enhancement and Intelligence Preparation	Adversaries can use their own space capabilities to enhance their military forces and prepare for potential conflicts. [44]	1. Resilient Architectures 2. Space Domain Awareness 3. Secure Communication Protocols and Encryption: 4. Intrusion Detection and Prevention	1. Satellites are designed to be resilient, meaning they can withstand attacks and continue to function. This can involve using redundant systems, so if one satellite is disabled, others can take over its functions. [44] 2. Military organizations monitor space closely to detect potential threats as early as possible. This includes tracking space debris and monitoring the activities of other countries in space. [44] 3. Establishing secure communication protocols and implementing end-to-end encryption for data transmission are fundamental countermeasures. This ensures that even if data is intercepted, it cannot be understood. 4. By leveraging signatures and machine-learning, cyber intrusions can be detected and blocked as craft payloads. This helps to identify and respond to threats in real time.

Table 14 – Satellite threats and countermeasures. [1] [2]

In addition to the dedicated space force, several units have been formed to develop expertise in both defence and attack postures in this domain. The US has built dedicated teams under the centralised command of their Combined Force Space Component Command.

From an Australian perspective, a Defence Space Strategy and dedicated Defence Space Command were announced in 2022. Now referred to as SPACECOMD, it was also mentioned as a key priority in the Defence Strategic Review released in May 2023, when space was removed from the RAAF to the Joint Capabilities Group to ensure it was viewed from a joint services perspective. SPACECOMD's SPA9360 is now taking an integrated approach to Space Domain Awareness (SDA). Launched in 2020, it consolidates the following programs: Air 3029 Phase 2, JP9350, JP9351, JP9352, JP9355, and JP9356. Many of these projects provide the capability for SPACECOMD's Remote Sensor Unit (1 RSU) to enhance the ADF's space presence and Space Situational Awareness (SSA). [80] 1 RSU achieve this capability with the C-band radar, Space Based Infrared System – Australian Mission Processor (SBIRS-AMP) and (once fully operational) the Space Surveillance Telescope (SST).

The delivery of the Space Surveillance Telescope (SST) at Exmouth in Western Australia is a partnership between Australia and the US, with the 'First Light' milestone achieved in March 2020 and RAAF air surveillance operator training beginning in April 2021. The first demonstration of integration of the SST in the new facility followed in July. Construction of a Mirror Recoating Facility (MRF) designed, built and maintained by Australian industry from early 2022. [81]

In conclusion, military organisations use a combination of technical measures, operational strategies, and international cooperation to protect their satellites from threats.

Future Trends and Technologies

These trends and technologies are expected to shape the future of military satellites, enhancing their capabilities and resilience in the face of increasing threats. With the space economy growing from $630 million in 2023 to $1.8 trillion in 2035 [82] it will drive some of the most significant innovations since the Apollo space or Trident nuclear submarine programs. Much of this will be leveraged to attempt to give a nation superiority in space. I have selected the seven most profound and will outline each in this section.

Investments and Threats in Military Space Capability

To counter the US's advantage in space China has invested heavily in space capabilities and are massively ramping up their placement of satellites in space. Available figures on space investments include US $14 billion (2020), China $9 billion and Russia $3 billion all in US dollars. To counter the US's advantage, China is building upon their successful establishment of Tiangong Space Station, has launched a program to become "the world's dominant space power "economically, diplomatically, and militarily" by 2045". [83]China took a giant leap forward in 2021 when they tested a missile that can circumvent current threat warning and defensive systems (either space or ground based). In a move then Chairman of the Joint Chiefs of Staff, US General Mark Milley called a near 'Sputnik moment', China tested a hypersonic missile that nearly orbited the globe before returning to hit a target, providing them with the ability to conduct what is referred to as 'fractional orbital bombardment'. [84]

Despite their public rhetoric against the militarisation of space, much of China's investment is being channelled into advanced space capability, both kinetic and non-kinetic. [85] This investment of the militarisation of space has caused alarm with the US Department of Defence who provided a recent report to Congress entitled "Military and Security Development Involving the People's Republic of China". [86] Likewise, the US Office of the Director of National Intelligence in its March 2024 threat assessment called out "daily threats" from the Chinese in Space, these included counterspace capabilities, directed energy and anti-sat systems. An example of this is the daily instance of satellite frequency jamming. [87] To help maintain US dominance in space their Department of Defence identified a future budget of $33.7 billion was required for in fiscal year 2025 and including investments: $2.4 billion for space launch capabilities; $1.5 billion for more resilient position, navigation and timing; $4.2 billion for more resilient and protected satellite communications; $4.7 billion to develop new missile warning and tracking architectures and $12.3 billion for a range of other capabilities aimed at increasing the resiliency of DOD's existing space architectures. [96]

To neutralise or at a minimum stay competitive with the Chinese threat, the pursuit of the following technologies will be vital, modularity, high throughput geostationary orbits, laser and quantum satellite communication, satellite miniaturisation and the application of artificial intelligence. These opportunities and threats are outlined below.

Modularity

Modularity is set to revolutionise the future of military satellites. This approach involves using standardised components that can be easily replaced or upgraded, enhancing the flexibility and longevity of satellite systems.

In the context of military satellites, modularity can significantly improve responsiveness. If a module fails or becomes outdated, it can be replaced without needing to decommission the entire satellite.

This not only extends the lifespan of the satellite, but it also ensures that it can be continually updated with the latest technology.

Moreover, modularity can enhance the resiliency of military satellites. In a modular system, the failure of one component does not necessarily compromise the entire system. This is particularly important in a military context, where satellites must be able to withstand hostile actions and continue to operate even in adverse conditions.

Finally, modularity can lead to cost savings. Standardised components can reduce development time and costs, as well as those associated with launch and operation.

In conclusion, modularity is expected to profoundly impact the future of military satellites, offering enhanced flexibility, resilience, and cost-effectiveness. It represents a significant step forward in the evolution of space technology.

High-Throughput Geostationary Orbits and Proliferated Low-Earth Orbit Satellites

High-Throughput Geostationary Orbits (HTGEOs) and Proliferated Low-Earth Orbit (pLEO) satellites are set to significantly enhance military satellite capabilities. HTGEOs can provide robust, wide-area coverage, enabling high-speed data transmission.

This is crucial for real-time military communications and surveillance. On the other hand, pLEO satellites, due to their proximity to Earth, offer lower latency and increased resilience. They can be rapidly deployed and replaced, providing flexibility in response to evolving threats.

Together, HTGEOs and pLEO satellites represent a powerful combination that can ensure secure, reliable, and resilient space-based capabilities for future military operations.

Laser Communication Technology

Laser Communication Technology is poised to revolutionise military satellite communications. It offers secure, high-speed data transmission, which is critical for real-time military operations. Unlike traditional radio frequency communications, laser communications are less susceptible to interference and eavesdropping, enhancing the security of military communications.

Additionally, laser communication systems are compact and lightweight, making them ideal for space applications. As this technology matures, it is expected to significantly enhance the capabilities of military satellites, providing a secure and efficient means of communication for future military operations.

Quantum Satellite Communication

Quantum Satellite Communication is anticipated to be a momentous change for defence satellites. This technology uses the principles of quantum mechanics to create unbreakable encryption for data transmission. This means that any attempt to intercept or eavesdrop on the communication would be immediately noticeable, providing an unprecedented level of security for sensitive military information.

Moreover, Quantum Satellite Communication could potentially offer higher data transmission rates, which would significantly enhance the efficiency and speed of communication between defence satellites and ground stations. This could enable real-time coordination of defence operations, even in remote or hostile environments.

As this technology continues to evolve, it could also pave the way for quantum networks in space, providing global coverage for quantum communication. This would significantly bolster the capabilities of defence satellites, making them an even more integral part of future military operations. Quantum Satellite Communication could redefine secure space-based communication in the defence sector.

Chinese already have a head-start in this area. In 2016 they deployed Mozi, the world's first satellite to test quantum communications by sending quantum entangled photons long distances using lasers as their transport medium across space to precise targets on earth. [88] [89] This delivered a communications network based upon subatomic particles that leveraged quantum encryption that was un-hackable, not only could it not be broken, nor could it be eavesdropped on for the application of other kinds of exploitation such as traffic analysis; an often forgotten, but vital component of SIGINGT. It is now believed to form the basis of ultra-secure satellite communications and the provision of a quantum network backbone, which would provide a significant advantage in C4ISR capabilities.

This would deny the US one of their most powerful advantages, as demonstrated during the first Gulf War, where they comprehensively dominated the EMS domain.

Miniaturisation and Smaller Satellites

The trend towards miniaturisation and smaller satellites will significantly impact military satellites. These compact satellites, often referred to as CubeSats or NanoSats, are cost-effective to launch and can be deployed in large numbers, creating a resilient network that is less vulnerable to attacks or failures.

They can be equipped with advanced technologies for surveillance, communication, and data transmission and their small size makes them less detectable, enhancing their security. As technology advances, these miniaturised satellites are expected to play an increasingly significant role in defence, providing robust, flexible and secure space-based capabilities.

The following are examples of how CubeSats or NanoSats are being used to improve the warfighting capabilities of military satellites.

U.S. Military's Use of CubeSats

The U.S. military has been exploring the use of CubeSats to improve battlefield communications, monitor space weather, and gather data from unattended sensors. [90] For instance, the U.S. Army launched a triple-unit CubeSat to prove the ability of small satellites to transfer data to and from unattended ground sensors. [90]

AI and Machine Learning in NanoSats

The U.S. military is harnessing algorithms and machine learning for small-form-factor space applications. For example, the Space and Engineering Research Center at the University of Southern California's Information Sciences Institute is working on a project with four La Jument nanosatellites to enhance AI and ML space technologies. [91] These nanosats will enable AI/ML algorithms in orbit, thanks to advanced multicore processing and onboard graphics-processing units. [91]

AI and ML Impact Upon Military Satellites

Artificial Intelligence (AI) and Machine Learning (ML) are set to significantly enhance the warfighting capabilities of military satellites. Here's how:

Improved Space Domain Awareness (SDA)

AI can help generate a comprehensive catalogue of known and observed Earth-orbiting objects, by continuously monitoring and assessing the probability of collisions and alerting operators in the event of heightened risk.

Enhanced Image Analysis

AI can analyse and sort captured images from reconnaissance satellites, improving the efficiency of data transmission to ground stations.

Autonomous Satellite Technology

Advances in AI and ML are expected to lead to new developments in autonomous satellite technology, characterised by increased capabilities, greater security, and more flexible and agile platforms.

False Track Reduction

ML can simplify the process of discovering, classifying, and monitoring missile launches across the globe by leaning on pattern-recognition capabilities.

Transforming ISR Capabilities

Major impacts from AI, ML and big data in the observation function can efficiently and effectively collect, assimilate, and process enormous amounts of data to identify potential targets.

These advancements are expected to provide a significant edge in future warfare, ensuring secure, reliable, and efficient space-based capabilities.

Conclusion

We have now landed in a place where space has joined, land, sea, air and cyber as a defined domain. Indeed, space and cyber are the most effective for asymmetric non-kinetic warfare and are under constant attack. The combination of cyber and space through the targeting of communications is particularly potent. Recent developments in navigation warfare (NAVWAR) are also significant, potentially impacting the deployment of sophisticated technologies such as hypersonic missiles, drones and unmanned underwater vehicles.

At the time, it was treated with some derision by the popular press. However, the formation of the US Space Force, a reannouncement of the US Strategic Command as a dedicated service line, has now been followed by most nations. Given the opportunities, challenges, and risk in this domain it’s increasingly seen as a smart decision to highlight this domain’s importance as an integral part of the future of warfare.

Appendix A – Australian Satellite Launches

Satellite	Date	Type	Orbit	Owner	Builder	Function	Launched	Status	Notes	Inactive
Djara	03/10/20		LEO	Office of National Intelligence (ONI)	Spire Global	Communications / Scientific	Wallops Island, Virginia	operating	data experiments designed to explore future possibilities of commercially available small, smart satellite systems.	
NICSAT-2	13/01/22		LEO	Office of National Intelligence (ONI)	Spire Global and Dragonfly Aerospace	Scientific / Intelligence	SpaceX's Transporter-3 mission	operating	Including the on-board advanced machine learning capabilities for small satellites.	
SKY MUSTER 1	1/10/2015	Large	GEO	NBN Co Limited	SSL	Communications	Guiana Space Centre in French Guiana, South America14.	15 Years	Provide broadband NBN in lieu of fibre.	2030
SKY MUSTER 2	5/10/2016	Large	GEO	NBN Co Limited	SSL	Communications	Guiana Space Centre in French Guiana, South America14.	15 Years	Provide broadband NBN in lieu of fibre.	2031
TYVAK-0171 (EG 2)	03/09/20	Mini	LEO	EchoStar Global LLC	Tyvak Nano-Satellite Systems	S-band IoT (Internet of Things) constellation	Europe's Spaceport, Kourou, French Guiana	UNK	It decayed and re-entered on February 8, 2024	Between 2023-2033 due to Cube Sat configuration)
TYVAK-0172 (EG 1)	30/08/20	12 kg.	LEO	EchoStar Global LLC	Tyvak Nano-Satellite Systems	S-band IoT (Internet of Things) constellation	Air Force Eastern Test Range, Florida, USA	UNK		Between 2023-2033 due to Cube Sat configuration)
BUCCANEER RMM	18/11/17	4 kg.	SSO	UNSW / Defence / DSTG	UNSW / Defence / DSTG	Scientific / Military	Vandenberg Air Force Base in California, United States	5	Calibrate the Jindalee Over-the-Horizon Radar Network (JORN). Acquire high-quality flight data for correlated Astrodynamics and Space Situational Awareness (SSA) experiments.	2023
I-INSPIRE II (AU03) (Cubesat)	26/05/17	1.75 kg	SSO	USyd, UNSW, and ANU.	University of Sydney.	Scientific	International Space Station by Nanoracks following an Atlas V launch.	0.5 years/ 6 months	The satellite was brought online a month after launch due to a major campaign with the international amateur radio community. While INSPIRE-2's radio beacons were resurrected and continued for over a year, the Communications board's handshaking protocols meant that downlinking of data was not possible. Part of the QB50 mission, which involves conducting multi-point, in-situ, long duration measurements of different gaseous molecules and electrical properties of the previously inaccessible thermosphere.	Decayed
SUSAT(AU01)	18/04/17	2 kg	LEO	University of Adelaide	University of Adelaide	Scientific	Cape Canaveral Air Force Station Space Launch Complex 41 (CC SLC-41).	satellite has re-entered and is no longer in orbit.3 months	2U-CubeSat it is part of the QB50 constellation to gather science data in the upper layers of the troposphere in the altitude range from 350 km down to 200 km.	Decayed
UNSW-ECO (AUO2)	02/12/16	Nano	LEO	University of New South Wales	University of New South Wales	Scientific	Wallops Island, Virginia, USA	satellite has re-entered and is no longer in orbit.	QB50 project, a network of 50 CubeSats that were launched together into a 'string-of-pearls' configuration in a circular orbit at 320 km altitude1. The launch was carried out by an Orbital ATK Antares rocket from The satellite is part of the QB50 mission, which involves conducting multi-point, in-situ, long duration measurements of different gaseous molecules and electrical properties of the poorly studied and previously inaccessible thermosphere.	Decayed
SIRION PATHFINDER II	03/12/18			Sirion Global	for Sirion Global's	Internet-of-Things (IoT)	Air Force Western Test Range, California, USA	UNK	satellite is part of a constellation of approximately 28 satellites in low Earth orbit.	Between 2023-2033 due to Cube Sat configuration)
Centauri 2	29/11/18			Fleet Space Technologies	Pumpkin Space Systems	Internet-of-Things (IoT)	Satish Dhawan Space Centre in Sriharikota, India.	Centauri 2 has decayed and is no longer in orbit3 Years	satellite is part of a constellation of approximately 28 satellites in low Earth orbit.	Decayed
M2 Pathfinder	13/06/20	2	LEO	University of New South Wales (UNSW) Canberra Space researchers and engineers and the Royal Australian Air Force (RAAF)	University of New South Wales	Communications / Scientific	Mahia Peninsula, New Zealand.	Operational	testing the various in-house technologies including on-board computing, attitude control, GPS, optical imaging, communications, and flight software on the spacecraft is under way and proving to be successful which assists in informing the future space capabilities of Australia.	Between 2023-2033 due to Cube Sat configuration)
WRESAT	29/11/67	45 k		Weapons Research Establishment (WRE) and the University of Adelaide	Weapons Research Establishment (WRE) University of Adelaide	Scientific	Woomera, South Australia	January 10, 1968, over the Atlantic Ocean west of Ireland	WRESAT satellite completed 642 orbits and transmitted scientific (upper atmospheric radiation) information for 73 of these to tracking and research stations around the world. It was also the first to be designed for remote control operations by amateur radio operators.	Decayed
Australis - OSCAR 5 (AO-5)	23/01/70	18	LEO	University of Melbourne	University of Melbourne	beacon broadcasting a signal on two wavebands popularly used by radio amateurs around the world	Vandenberg Air Force Base, Lompoc, California.	The satellite is no longer operative,	. It transmitted data from seven different onboard sensors on two wavebands, 2 metre and 10 metre, commonly used by radio amateurs. But it remains in orbit as part of Australia's space heritage. It operated successfully for over six weeks.	Decayed
OPTUS AUSSAT A1	27/08/85	654 kg	GEO	Commonwealth Bank of Australia owns the satellite and leases it back to Singtel Optus	Hughes Communications International	provide radio and television services to Australia's remote areas	Space Shuttle Discovery	15 Years		2023 (already debris)
OPTUS AUSSAT A2	27/11/85	654 kg	GEO	Commonwealth Bank of Australia owns the satellite and leases it back to Singtel Optus	Hughes Communications International,	Communications	Space Shuttle Atlantis	15 Years	provide radio and television services to Australia's remote areas	2023 (already debris)
OPTUS AUSSAT A3	16/09/87	1195	Geosynchronous	CBA Singtel Optus	Hughes Communications International	Communications	Kourou Space Center, French Guiana	15 Years OPTUS AUSSAT A3 was moved to a graveyard orbit and shut down in April 2008. It is no longer active.	subscription-TV, free-to-air TV, radio, internet, voice, and data services across Australia, New Zealand, Southeast-Asia, Hawaii, Norfolk Island, Papua New Guinea, Lord Howe Island, Cocos-Keeling Islands, Christmas Island and McMurdo Sound	2023 (already debris)
OPTUS AUSSAT B2	21/12/92	2350	GTO	CBA Singtel Optus	Hughes Space and Communications Company in El Segundo, California.	Long March 2E rocket carrying OPTUS B2 experienced a collapse of the payload fairing, destroying the satellite.	Xichang Satellite Launch Center by Long March rockets	UNK	The rocket continued functioning and delivered the debris into low Earth orbit satellite was used to enhance existing satellite communications services throughout Australia, including direct television broadcast to homesteads and remote communities, voice communications to urban and rural areas, digital data transmission, high-quality television relays between major cities, and centralized air traffic control services.	Decayed
OPTUS AUSSAT B1	13/08/92	1659 k	GEO	CBA Singtel Optus	Hughes Space and Communications Company		Xichang Satellite Launch Center, China.	Junk Orbit	satellite was moved to Junk orbit in May 2008 Optus B1 introduced the first domestic mobile satellite communications network to Australia.	2023 (already debris)
OPTUS AUSSAT B3	28/08/94	2,800 kg		CBA Singtel Optus	Hughes Space and Communications Company	Communications	Xichang Satellite Launch Center, China.	15 Years	Digital data transmission, high-quality television relays between major cities, remote and rural areas and centralized air traffic control services.	2023 (already debris)
WESTPACT	10/07/98	23.8 kg	SSO	Electro Optic Systems Pty Limited (EOS)	Russian Institute of Space Device Engineering (RISDE) of Moscow	passive satellite. Its objective is to enhance the contribution of satellite laser ranging (SLR), particularly to space geodesy in the Western Pacific	Baikonur Cosmodrome, Kazakhstan	The passive spacecraft with its onboard retroreflector array was functional for SLR tracking as of 2012.	It also serves in the development of free space optical communications and studies the Fizeau effect that occurs when laser light is reflected from a satellite traveling at orbital velocities.	Many decades predicted
FedSat	14/12/02	58 kg	SSO	Cooperative Research Centre for Satellite Systems (CRCSS)	Space Innovations Limited	Communications / Scientific	Tanegashima Space Centre in Japan	May 2007	The spacecraft's battery failed in May 2007 and the mission has been terminated, after lasting 18 months longer than expected.	Decayed

OPTUS C1	12/06/03	4,800 kg	GEO	Optus	Mitsubishi Electric	The Department of Defence has extended its long-running C1 satellite contract with Optus until its new "sovereign controlled" military satellite communication constellation comes online.	Guiana Space Centre in French Guiana, South America.	Active	15 Years (expected use until 2034	2034
OPTUS D1	13/10/06	2,300 kg	GEO	Optus			Kourou	15 Years + 5 years extended lifetime (Optus)		2026
OPTUS D2	12/10/07	2,460 kg	GEO	Optus	Orbital Sciences Corporation	fixed and broadcasting communications services.	Guiana Space Centre in French Guiana, South America14.	15 Years + 5 years extended lifetime (Optus)	It provides ongoing capacity for ethnic broadcast services and VSAT services plus growth to meet future business demands.	2027
OPTUS D3	21/08/09	2,500 kg	GTO	OPTUS	Orbital Sciences Corporation	Australia in the BSS band and is co-located with the Optus C1 satellite to provide enhanced capability for Australia's prime orbital location delivering direct-to-home services across Australia	Guiana Space Centre in French Guiana, South America14.	Active	15 Years + 6 years extended lifetime (Optus). It also provides FSS band back up capacity to New Zealand.	2031
OPTUS 10	11/09/14	3270 kg.	GEO	OPTUS	Space Systems/Loral (SS/L)	Voice, data, and video services across mainland Australia, New Zealand, and Australia's surrounding islands and territories.	Guiana Space Centre in French Guiana, South America14.	Active	15 Years + 5 years extended lifetime (Optus)	2029
SKY MUSTER 1	30/09/15	6,440 k	Geostationary	NBN Co Limited	SSL	Communications, data	Guiana Space Centre in French Guiana, South America	15 Years (Gunter's space page)	satellite is operational and provides high-speed broadband service to 400,000 Australian homes and businesses in rural and remote Australia. As of June 2020, there are over 100,000 active customers connected to a Sky Muster service.	2030
M1	03/12/18	4 kg	LEO	UNSW ADFA RAAF	UNSW ADFA RAAF	M1 satellite was a flight demonstration of several key technologies and operations. It aimed to deliver AIS / ADS-B capability across the globe using COTS AIS and ADS-B systems.	Vandenburg Air Force Base in California	Decayed	It also aimed to test, validate, and further develop Australian SSA capabilities by providing engineering design and performance data for the design of future passive radar systems to track LEO spacecraft. Despite considerable effort and a rigorous analysis, communication with the M1 satellite could not be established after launch.	2023 (already debris)
Centauri 1	03/12/18		LEO	Fleet Space Technologies	Fleet Space Technologies; Pumpkin (bus)	Pathfinder satellite for global satellite connectivity to the Internet-of-Things (IoT)	Air Force Western Test Range, California, USA	Inactive No Information		Between 2023-2033 due to Cube Sat configuration)
Proxima 2	11/11/18	1.5U CubeSat	LEO	Fleet Space Technologies	Pumpkin Space Systems	network of Centauri satellites for global satellite connectivity to the Internet of Things (IoT).	Rocket Lab's launch site in New Zealand	Operational		Between 2023-2033 due to Cube Sat configuration)
Centauri 2	29/11/08		LEO	Fleet Space Technologies	Fleet Space Technologies; Pumpkin (bus)	Pathfinder satellite for global satellite connectivity to the Internet-of-Things (IoT)	Sriharikota, India			
Proxima 1	11/11/18	1.5U CubeSat	LEO	Fleet Space Technologies	Pumpkin Space Systems	network of Centauri satellites for global satellite connectivity to the Internet of Things (IoT).	Rocket Lab's launch site in New Zealand	Operational		Between 2023-2033 due to Cube Sat configuration)
ACRUX 1	29/06/19	1 kg	LEO	Melbourne Space Program	Melbourne Space Program	develop, build, and launch a student-built CubeSat from scratch.	Launch Complex 1, located on the Mahia Peninsula in New Zealand.	Decayed	to test the functionality of the subsystems, and to develop the basics for future satellite missions.	Decayed
TYVAK-0171 (EG 2)	03/09/20	12 kg	LEO	EchoStar Global LLC	Tyvak Nano-Satellite Systems	is part of an S-band IoT (Internet-of-Things) constellation by EchoStar Global.	Spaceport, Kourou, French Guiana.	no longer in orbit.	It is designed to provide narrowband data services, including machine-to-machine and Internet-of-Things communications	Between 2023-2033 due to Cube Sat configuration)
M2-A	22/03/21		LEO	ADFA RAAF	UNSW	Earth observation, maritime surveillance, and satellite communications.	Rocket Lab's launch site in New Zealand.	Operational	It is part of a 12U CubeSat which split into two 6U CubeSats (M2-A and M2-B). M2-A satellite was operational and successfully separated from its twin, M2-B.	Between 2023-2033 due to Cube Sat configuration)
M2-B	22/03/21		LEO	ADFA RAAF	UNSW	Earth observation, maritime surveillance, and satellite communications.	Rocket Lab's launch site in New Zealand.	Operational	It is part of a 12U CubeSat which split into two 6U CubeSats (M2-A and M2-B). M2-A satellite was operational and successfully separated from its twin, M2-B.	Between 2023-2033 due to Cube Sat configuration)
CENTAURI-3	22/03/21	10kg	LEO	Fleet Space Technologies	Fleet Space Technologies; Pumpkin (bus)	Pathfinder satellite for global satellite connectivity to the Internet-of-Things (IoT) for use in the energy, utilities, and resource industries.	New Zealand's Launch Complex 1 at Mahia Peninsula	Operational	Centauri-3 is a pathfinder satellite for Fleet Space Technologies planned 140 satellite networks for global satellite connectivity to the Internet of Things (IoT).	2024
CENTAURI-4	30/06/21	11.3 kg.	LEO	Fleet Space Technologies	Fleet Space Technologies	The Centauri-4 satellite incorporates digital beamforming technology and can support voice communications	US launch site Cape Canaveral	Operational	It enables instant voice communication between two or more connected devices at the push of a button.	2024
MYRIOTA 7 (TYVAK-0152)	22/03/21	5	LEO	Myriota	Tyvak Nano-Satellite Systems, Inc	is part of an S-band IoT (Internet-of-Things) constellation by EchoStar Global.	Mahai Launch site in New Zealand.	Operational	The satellite is currently operational and is being tracked.	Between 2023-2033 due to Cube Sat configuration)
TYVAK-0173 (EG3)	29/06/21	12	LEO	Myriota	Tyvak Nano-Satellite Systems	EchoStar Global constellation and is used for Internet of Things (IoT) communications.	Air Force Eastern Test Range, Florida, USA.	Operational	It provides narrowband data services, including machine-to-machine and Internet-of-Things communications, throughout the globe.	Between 2023-2033 due to Cube Sat configuration)
CUAVA 1	29/08/21	3	LEO	CUAVA Training Centre	CUAVA Training Centre with UNSW and USyd.	Investigate Earth's plasma environment and space weather using onboard radiation detectors.	Kennedy Space Center at Cape Canaveral, Florida	On board the International Space Station awaiting deployment into orbit.	Observe Earth using novel imaging technology and test equipment designed for use in a future satellite that will search for signs of life on planets around Alpha Centauri, our nearest star system.	Decayed
Binar 1	29/08/21	2kg	LEO	Curtin University	Curtin University	technology demonstration mission. Its main objective was to test innovative design, with all systems integrated on a single circuit board at its core, would survive in space	Kennedy Space Centre in Florida, US.	Decayed	It was equipped with two cameras, with the objectives of photographing Western Australia from space and imaging stars Its last recorded transmission was on November 2, 2021.	Decayed
Centauri-5	25/05/22	12kg	LEO	Fleet Space Technologies	Fleet Space Technologies	designed to enhance global connectivity for the Internet of Things (IoT)..	Space Launch Complex 40 at Cape Canaveral, Florida.	Operational	It also supports the development of Fleet Space's forthcoming Alpha constellation, which enables their pioneering ExoSphere by Fleet® mineral exploration tool.	Between 2023-2033 due to Cube Sat configuration)
Centauri-6	08/04/24	12kg	LEO	Fleet Space Technologies	Fleet Space Technologies	designed to enhance global connectivity for the Internet of Things (IoT).	Kennedy Space Centre in Florida, US.	Operational	It also supports the development of Fleet Space's forthcoming Alpha constellation, which enables their pioneering ExoSphere by Fleet® mineral exploration tool.	Between 2023-2033 due to Cube Sat configuration)
Optimus	05/03/24	270	LEO	Space Machines Company	Space Machines Company	Repair and refuel other space infrastructure. It also tests state-of-the-art printed solar cells developed by the CSIRO	Vandenberg Space Force Base California	Operational		
Skykraft-1	03/01/23	300	LEO	Skykraft	Skykraft	Surveillance services to track aircraft in flight and communications services.	Cape Canaveral, United States	Operational	Part of a constellation that will improve communications between air traffic controllers and pilots.	2028
Skykraft-1D	03/01/23	300	LEO	Skykraft	Skykraft	As above.	Air Force Eastern Test Range, Florida, USA.	Operational	Part of a constellation that will improve communications between air traffic controllers and pilots.	2028
Skykraft-1A	03/01/23	300	LEO	Skykraft	Skykraft	As above.	As above.	Operational	As above.	2028
Skykraft-1B	03/01/23	300	LEO	Skykraft	Skykraft	As above.	As above.	Operational	As above.	2028
Skykraft-1C	03/01/23	300	LEO	Skykraft	Skykraft	As above.	Cape Canaveral, United States	Operational	As above.	2028
Skykraft-3	19/04/23	300	LEO	Skykraft	Skykraft	As above.	Air Force Western Test Range, California, USA.	Operational	As above.	2028
Skykraft-3A	12/06/23	300	LEO	Skykraft	Skykraft	As above.	As above.	Operational	As above.	2028
Skykraft-3B	12/06/23	300	LEO	Skykraft	Skykraft	As above.	As above.	Operational	As above.	2028
Skykraft-3C	12/06/23	300	LEO	Skykraft	Skykraft	As above.	As above.	Operational	As above.	2028

Bibliography

[1] "Space News," [Online]. Available: https://spacenews.com/chinas-2024-space-plans-include-100-launches-and-moon-sample-return-mission/.

[2] A. D. o. D. Defence, "SPace Power Emanual - Light Speed Edition," Commonwealth of Australia, Canberra, 2022.

[3] "GeoNumber," [Online]. Available: https://www.geospatialworld.net/prime/business-and-industry-trends/how-many-satellites-orbiting-earth/.

[4] "ACMA," [Online]. Available: https://www.acma.gov.au/sites/default/files/2019-11/aust_procedures-coordination_notification_of_satellite_systems pdf.pdf.

[5] S. Foundation. [Online]. Available: https://www.spacefoundation.org/space_brief/international-space-law/.

[6] "UN Office for Outer Space Affairs," [Online]. Available: https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html.

[7] [Online]. Available: https://www.forbes.com.au/news/innovation/gilmour-space-launching-first-rocket-from-aus-in-50-years/.

[8] "Australian Space Agency," [Online]. Available: https://www.space.gov.au/moon-mars-initiative.

[9] "Australian Space Agency," [Online]. Available: https://www.space.gov.au/news-and-media/funding-boost-to-grow-aussie-space-sector.

[10] "Global Australia," [Online]. Available: https://www.globalaustralia.gov.au/news-and-resources/news-items/australias-space-industry-star-rise.

[11] "Wikipedia," [Online]. Available: https://en.wikipedia.org/wiki/Wideband_Global_SATCOM.

[12] "Aerospace," [Online]. Available: https://www.aerospace-technology.com/projects/wgs-satellite/.

[13] "Defense.info," [Online]. Available: https://defense.info/re-shaping-defense-security/2021/03/australias-quest-for-sovereign-satcom/.

[14] "Australian Defence," [Online]. Available: https://www.australiandefence.com.au/news/network-centric-warfare-satcoms-a-work-in-progress.

[15] ASPI, "ASPI," [Online]. Available: https://www.aspistrategist.org.au/australias-wgs-communications-what-went-wrong/.

[16] "Australian Defence Force," [Online]. Available: https://www.defence.gov.au/news-events/releases/2023-04-03/lockheed-martin-deliver-defence-satellite-communication-system.

[17] [Online]. Available: https://www.australiandefence.com.au/news/news/defence-confirms-jp9102-cancellation.

[18] "Space Memerise," [Online]. Available: https://spacemesmerise.com/blogs/space-technology/satellite-surveillance-transforming-military-intelligence-gathering.

[19] "Rand," [Online]. Available: https://www.rand.org/content/dam/rand/pubs/perspectives/PE200/PE273/RAND_PE273.pdf.

[20] "Atlas News," [Online]. Available: https://theatlasnews.co/conflict/2022/03/05/satellite-signals-intelligence-collection-in-the-near-peer-competition-era/.

[21] "Defense Bridge," [Online]. Available: https://defensebridge.com/article/the-role-of-military-satellites-in-national-security.html.

[22] NRO. [Online]. Available: https://www.nro.gov/foia-home/foia-sigint-satellite-story/.

[23] Wikipedia. [Online]. Available: https://en.wikipedia.org/wiki/Timeline_of_artificial_satellites_and_space_probes.

[24] J. Richelson, The U.S. Intelligence Community, Ballinger, Cambridge, MA, 1985.

[25] "Space News," [Online]. Available: https://spacenews.com/spacex-launches-u-s-military-weather-monitoring-satellite/.

[26] "Invasion Tip," *Aviation Week & Space Technology,* p. 15, 6 August 1990.

[27] "Space News," [Online]. Available: https://spacenews.com/spacex-launches-u-s-missile-defense-satellites/.

[28] S. News. [Online]. Available: https://spacenews.com/spacex-launches-u-s-military-weather-monitoring-satellite/.

[29] IISS, "IISS," [Online]. Available: https://www.iiss.org/online-analysis/military-balance/2022/02/uk-defence-space-strategys-orbital/.

[30] B. Carlson, Interviewee, *10 Who Made a Difference in Space: Bruce Carlson, NRO Director.* [Interview]. 11 August 2011.

[31] "Sat Track Cam," [Online]. Available: https://sattrackcam.blogspot.com/2019/09/image-from-trump-tweet-identified-as.html.

[32] J. Richelson, The wizards of Langley : inside the CIA's Directorate of Science and Technology, Boulder, Colo: Westview Press, 2002.

[33] "History.Net," [Online]. Available: https://www.historynet.com/spy-intelligence-from-the-sky/.

[34] Wired, "Wired," [Online]. Available: https://www.wired.com/story/trump-tweeted-a-sensitive-photo-internet-sleuths-decoded-it/.

[35] "Wikipedia.org/wiki/Reconnaissance_satellite," [Online]. Available: https://en.wikipedia.org/wiki/Reconnaissance_satellite.

[36] "The Intercept," [Online]. Available: NSA's documents, in the mid-1990s the U.S. intelligence community was convinced that satellite communications would soon become obsolete, to be fully replaced by fiber-optic cable networks..

[37] "National Reconnaissance Office," [Online]. Available: https://www.nro.gov/foia-home/foia-sigint-satellite-story/.

[38] "CSIRO," [Online]. Available: https://www.csiro.au/en/news/All/News/2022/March/National-Space-Mission-for-Earth-Observation.

[39] "AUSSA," [Online]. Available: https://www.space.gov.au/sites/default/files/media-documents/2023-04/earth_observation_from_space_roadmap.docx.

[40] "UNSW," [Online]. Available: https://www.unsw.edu.au/newsroom/news/2024/01/the-evolution-of-gps--what-to-expect-from-global-navigation-sate.

[41] "Computer World," [Online]. Available: https://www.computerworld.com/article/1370693/military-vs-civilian-gps.html.

[42] "Minister for Defence Australia," [Online]. Available: https://www.minister.defence.gov.au/media-releases/2014-08-26/minister-defence-upgrade-australian-defence-force-navigation-warfare-capability.

[43] "Institution of Electrical and Electronics Engineers," [Online]. Available: https://ieeexplore.ieee.org/document/10351029.

[44] "Center for Strategic and International Studies," [Online]. Available: https://aerospace.csis.org/wp-content/uploads/2018/09/Space-System-Threats.pdf.

[45] "GPS Time," [Online]. Available: https://www.thegpstime.com/managing-threats-to-military-satellite-spectrum/.

[46] "Defense Intelligence Agency," [Online]. Available: https://www.dia.mil/Portals/110/Documents/News/Military_Power_Publications/Challenges_Security_Space_2022.pdf.

[47] "Space.Com," [Online]. Available: https://www.space.com/anti-satellite-weapons-asats.

[48] “DTIC,” [Online]. Available: https://web.archive.org/web/20190117163253/https://apps.dtic.mil/dtic/tr/fulltext/u2/a955694.pdf.

[49] “BBC,” [Online]. Available: https://www.bbc.com/news/world-asia-india-47729568.

[50] “NASA,” [Online]. Available: https://www.nasa.gov/news-release/nasa-administrator-statement-on-russian-asat-test/.

[51] “National Interest,” [Online]. Available: https://nationalinterest.org/blog/reboot/could-russias-hypersonic-avangard-icbm-really-travel-20-times-speed-sound-169252.

[52] “Missile Threat,” [Online]. Available: https://missilethreat.csis.org/missile/avangard/.

[53] “DW Global Media Forum,” [Online]. Available: https://www.dw.com/en/chinese-space-cleaner-spotted-grabbing-and-throwing-away-old-satellite/a-60658574.

[54] “Mashable,” [Online]. Available: Spacecraft makes daring approach of metal object in Earth's orbit | Mashable .

[55] “Space.Com,” [Online]. Available: https://www.space.com/kessler-syndrome-space-debris.

[56] “Arms Control,” [Online]. Available: https://www.armscontrol.org/act/2024-03/news/us-warns-new-russian-asat-program#:~:text=In%202021%2C%20Russia%20conducted%20an,have%20demonstrated%20ASAT%20missile%20capabilities..

[57] “Peterson Schriever,” [Online]. Available: https://www.petersonschriever.spaceforce.mil/About-Us/Fact-Sheets/Display/Article/2286483/space-delta-2-space-domain-awareness/#:~:text=Space%20Domain%20Awareness%20encompasses%20the,or%20environment%20of%20our%20Nation..

[58] “Space News Bluestaq IS,” SN, [Online]. Available: https://spacenews.com/bluestaq-gets-new-investor-to-fund-growth-in-defense-and-space-data-management/.

[59] “Australian Defence,” [Online]. Available: https://www.australiandefence.com.au/news/news/space-command-using-kbr-s-iron-stallion.

[60] “spacecomm,” [Online]. Available: https://www.australiandefence.com.au/news/news/space-command-using-kbr-s-iron-stallion.

[61] “GMP,” [Online]. Available: https://www.globaldatamarketplace.com/marketplace/#/.

[62] [Online]. Available: Closed ATM View - DSPC_SSA_PWS_001/23.: AusTender .

[63] [Online]. Available: https://spacenews.com/russian-spy-satellite-reportedly-continues-suspicious-maneuvers/.

[64] [Online]. Available: https://www.eurasiantimes.com/starlink-killer-tech-russia-claims-developing/?amp#origin=https%3A%2F%2Fwww.google.com%2F&cap=swipe,education&webview=1&dialog=1&viewport=natural&visibilityState=prerender&prerenderSize=1&viewerUrl=https%3A%2F%2Fwww.google.co.

[65] “Lockheed Martin,” [Online]. Available: https://www.lockheedmartin.com/en-au/products/defence-satellite-communications.html.

[66] “SPace News,” [Online]. Available: https://spacenews.com/u-s-military-to-boost-surveillance-assets-in-orbit/.

[67] D. Ball, “Canberra Papers on Strategy and Defence No 43 - Australia's Secret Space Programs,” Strategic and Defence Studies Centre, Australain National University, Canberra, 1988.

[68] [Online]. Available: https://theconversation.com/russians-reportedly-building-a-satellite-blinding-laser-an-expert-explains-the-technology-186890.

[69] “Space Security,” [Online]. Available: https://spacesecurityindex.org/2020/11/electromagnetic-interference-with-space-systems/.

[70] Youtube. [Online]. Available: https://www.youtube.com/watch?v=8IGsQoL1AgQ.

[71] “CNBC,” [Online]. Available: https://www.cnbc.com/2022/02/28/ukraine-updates-viasat-says-cyber-event-disrupting-satellite-internet-service.html.

[72] “Trustwave,” [Online]. Available: https://www.trustwave.com/en-us/resources/blogs/spiderlabs-blog/killnet-claims-attacks-against-starlink-whitehousegov-and-united-kingdom-websites/.

[73] “Dark Readng,” [Online]. Available: https://www.darkreading.com/cyberattacks-data-breaches/hackers-claiming-wagner-group-ties-down-russian-satellite-internet-comms-.

[74] “Youtube,” [Online]. Available: https://www.youtube.com/watch?v=8e7MekHdSoQ.

[75] “MIT,” [Online]. Available: https://www.technologyreview.com/2022/05/10/1051973/russia-hack-viasat-satellite-ukraine-invasion/.

[76] “Defense Scoop,” [Online]. Available: https://defensescoop.com/2023/09/14/unclassified-space-policy/.

[77] “Defense One,” [Online]. Available: https://www.defenseone.com/policy/2024/04/military-force-could-be-directed-protect-private-sector-orbital-assets-dod-strategy-says/395459/.

[78] “DSIAC,” [Online]. Available: https://dsiac.org/technical-inquiries/notable/technologies-and-strategies-to-protect-satellites-from-cyber-and-electronic-warfare/.

[79] "Defense Bridge," [Online]. Available: https://defensebridge.com/article/the-role-of-military-satellites-in-national-security.html.

[80] [Online]. Available: 1 RSU Space Systems > Peterson and Schriever Space Force Base > Display .

[81] [Online]. Available: U.S. Space Surveillance Telescope in Australia achieves initial operational capability > Space Operations Command (SpOC) > Article Display .

[82] WEF, "WEF," [Online]. Available: https://www.weforum.org/agenda/2024/04/space-economy-technology-invest-rocket-opportunity/.

[83] "Defense One," [Online]. Available: the world's dominant space power "economically, diplomatically, and militarily" by 2045..

[84] "ABC News," [Online]. Available: https://www.abc.net.au/news/2021-10-28/us-milley-confirms-chinese-hypersonic-weapons-test/100576522.

[85] "Space News," [Online]. Available: https://spacenews.com/pentagon-report-chinas-space-strategy-shaped-by-technological-change/.

[86] "US Dod," [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://media.defense.gov/2022/Nov/29/2003122279/-1/-1/1/2022-MILITARY-AND-SECURITY-DEVELOPMENTS-INVOLVING-THE-PEOPLES-REPUBLIC-OF-CHINA.PDF.

[87] "USDNI," [Online]. Available: https://www.dni.gov/index.php/newsroom/reports-publications/reports-publications-2024/3787-2024-annual-threat-assessment-of-the-u-s-intelligence-community.

[88] "New Scientist," [Online]. Available: https://www.newscientist.com/article/2101071-china-launches-worlds-first-quantum-communications-satellite/.

[89] "Institute of Physics," [Online]. Available: https://physicsworld.com/a/china-launches-worlds-first-quantum-science-satellite/.

[90] "Space News," [Online]. Available: https://spacenews.com/us-military-eyes-adapting-cubesats-battlefield-use/.

[91] "Military Embedded," [Online]. Available: https://militaryembedded.com/ai/machine-learning/nanosats-put-ai-at-the-edge-computing-to-the-test-in-space.

[92] "Spatial Post," [Online]. Available: https://www.spatialpost.com/types-of-satellites-in-remote-sensing/.

[93] "Nano Avionics," [Online]. Available: https://nanoavionics.com/blog/how-many-satellites-are-in-space/.

[94] "Space Acadamy," [Online]. Available: https://www.spaceacademy.net.au/spacelink/radiospace.htm.

[95] NSA. [Online]. Available: https://nsarchive.gwu.edu/briefing-book/intelligence/2023-03-13/whats-there-where-it-and-whats-it-doing-us-space-surveillance.

[96] F. Affairs. [Online]. Available: https://www.foreignaffairs.com/united-states/spying-space.

[97] “Shephardmedia,” [Online]. Available: https://www.shephardmedia.com/news/digital-battlespace/boeing-wins-us440-million-contract-for-12th-wideband-global-satcom-satellite/.

[98] “Austra;ian Depatment of Defence,” [Online]. Available: https://www.defence.gov.au/news-events/releases/2023-04-03/lockheed-martin-deliver-defence-satellite-communication-system.

[99] “Officer of the Director of National Intellegence,” [Online]. Available: https://www.dni.gov/index.php/newsroom/reports-publications/reports-publications-2023/3676-2023-annual-threat-assessment-of-the-u-s-intelligence-community.

[100] NPR, https://www.npr.org/2019/08/30/755994591/president-trump-tweets-sensitive-surveillance-image-of-iran.

[101] “Australian Deparment of Defence,” [Online]. Available: https://www.defence.gov.au/business-industry/industry-capability-programs/guided-weapons-explosive-ordnance-enterprise.

[102] “World Population Review,” [Online]. Available: https://worldpopulationreview.com/country-rankings/military-satellite-by-country.

[103] “White House,” [Online]. Available: https://www.whitehouse.gov/briefing-room/statements-releases/2022/04/18/fact-sheet-vice-president-harris-advances-national-security-norms-in-space/.

[104] [Online]. Available: https://spacenews.com/slingshot-aerospace-harnessing-ai-to-track-suspicious-satellites/.

Glossary

Apollo Space Program: A program by NASA that aimed to land humans on the moon and bring them back safely.

Artemis mission: A NASA mission to return astronauts to the Moon and then travel to Mars. Australia is a partner in this mission.

Artificial Intelligence (AI): AI is the theory and development of computer systems capable of performing tasks that historically required human intelligence, such as recognizing speech, making decisions, and identifying patterns1. AI is an umbrella term that encompasses a wide variety of technologies, including machine learning, deep learning, and natural language processing2.

ASAT (Anti-Satellite) capability: Invented by the Soviet Union in 1963, this refers to the ability to destroy satellites.

Autonomous Satellite Technology: Developments in AI and ML leading to new advancements in autonomous satellite technology, characterized by increased capabilities, greater security, and more flexible and agile platforms.

Australian Communications and Media Authority (ACMA): is Australia's regulator for telecommunications, broadcasting, and online content.

Australian Signals Directorate (ASD): An Australian government agency responsible for foreign signals intelligence (SIGINT), support to military operations, cyber warfare, and information security.

Australian Space Agency: A government body that supervises Australia's space activities.

Avanguard Hypersonic Glide Vehicle: A Russian hypersonic missile that can generate an explosive force even without its nuclear warhead.

Aussat-1/2/3: Australia's first domestic communications satellites, launched between 1985-87.

Black Sky Aerospace: An Australian company that manufactures solid rocket fuel, motors, and launch vehicles. It has received investment from Italian based Leonardo.

Bus: Guidance, Navigation and Control (GNCV), Antenna, Avionics and Power source of a satellite.

Civilian Applications: The non-military use of satellites, which can include weather forecasting, GPS navigation, satellite TV and radio, and many other applications.

COMINT (Communications Intelligence): COMINT refers to any intelligence that is gained from communication between people and/or groups.

Communication: In the context of military applications, communication refers to the use of satellites to provide secure, reliable, and instantaneous communication links between different units and command centers, regardless of their location on the globe.

Cortex: A satellite spectrum monitoring system developed by Australia's Defence Science and Technology Group (DSTG).

CubeSats: A type of miniaturized satellite for space research that is made up of multiples of 10×10×10 cm cubic units. See also NanoSats.

Cyber Attacks: Attacks that target the digital systems of satellites and their ground stations, potentially disrupting their operation or taking control of the satellites.

Cybersecurity Measures: Employing robust cybersecurity measures to protect satellites and ground stations from cyber-attacks. This includes using encryption, firewalls, intrusion detection systems, and other security technologies.

Defence Satellite Communications System: A system that the Australian Defence Force (ADF) relies heavily on for long-range communications.

Defence Science and Technology Group (DSTG): part of the Australian Department of Defence. DSTG provides science and technology support to safeguard Australia and its national interests. It was formerly known as Defence Scient and Technology Group (DSTO) were early pioneers in satellite technology.

Defensive Measures: Measures such as NAVWAR that seek to prevent adversarial electronic warfare countermeasures from interfering with operational use of GPS. This involves developing a new military signal (M-code) and developing new receivers that can utilize M-code and incorporate improved antijam and anti-spoofing technology.

Electronic Attacks: Attacks that interfere with the signals transmitted by satellites, including jamming and spoofing.

ELINT (Electronic Intelligence): ELINT refers to any intelligence that is gathered from electronic signals not directly used in communication, such as those emitted from radars, missiles, guidance systems, and aircrafts.

Enhanced Image Analysis: The use of AI to analyse and sort captured images from reconnaissance satellites, improving the efficiency of data transmission to ground stations.

False Track Reduction: The use of ML to simplify the process of discovering, classifying, and monitoring missile launches across the globe by leaning on pattern-recognition capabilities.

Five Eyes (FVEY) community: An intelligence alliance consisting of the United States, United Kingdom, Canada, Australia, and New Zealand.

Force Enhancement and Intelligence Preparation: The use of space capabilities by adversaries to enhance their military forces and prepare for potential conflicts.

Frequency: What frequencies does the satellite transmit on, including operation and maintenance and the content for the function it performs?

Frequencies: Satellites and ground stations use specific communication frequencies to ensure efficient and reliable data transmission. Different frequencies are used for uplink and downlink to avoid interference, with higher bandwidths allowing for faster data transmission.

Function: What task or tasks do satellites perform?

Future Imagery Architecture (FIA): A program to design a new generation of optical and radar imaging US reconnaissance satellites for the National Reconnaissance Office.

Geospatial Intelligence (GEOINT): Intelligence about the human activity on earth derived from the exploitation and analysis of imagery and geospatial information that describes, assesses, and visually depicts physical features and geographically referenced activities on the Earth.

Geosynchronous Orbit: An orbit that matches the Earth's rotation on its axis, which takes one sidereal day.

Geostationary Orbit (GEO): A special case of a geosynchronous orbit. It is a circular orbit located at an altitude of 35,786 kilometers above the surface of Earth with zero inclination to the equatorial plane.

Geostationary Transfer Orbit (GTO): A type of geocentric orbit that is highly elliptical. It is used as an intermediate step for satellites destined for geosynchronous or geostationary orbit.

GHOSTHUNTER: A SIGINT program that enabled persons of interest to be targeted as soon as they logged into their internet café.

Gilmour Space: An Australian company preparing to launch Australia's first locally made orbital rocket, the Eris.

Global Positioning System (GPS): A satellite-based radionavigation system owned by the United States government and operated by the United States Space Force.

Governance of Space: The use of space and satellites is governed by a complex framework of international and national laws and treaties. These legal instruments aim to promote the peaceful use of space, prevent the militarization of space, and ensure equitable access to space resources.

Ground Segment: The launch, operation, and maintenance of the satellite, typically by a series of earth stations and radio communications.

Guided Weapons Explosive Ordnance (GWEO): A program by the Australia's Department of Defence investing to establish a sovereign supply chain.

Hijacking: The unauthorized use of a satellite for transmission or seizing control of a signal.

Improved Space Domain Awareness: The use of AI to generate a comprehensive catalogue of known and observed Earth-orbiting objects, continuously monitor and assess the probability of collisions, and alert operators in the event of heightened risk.

Intelligence, Surveillance and Reconnaissance (ISR): The use of satellites to monitor activities around the world, providing detailed imagery of potential areas of interest, helping to identify military installations, troop movements, and other relevant information.

Interception (SIGINT): Signal Intelligence – Some military satellites are equipped to intercept and analyse foreign electronic emissions, such as radar (ELINT) and radio communications (COMINT).

International Cooperation: Working with allies and international organizations to promote responsible behaviour in space and discourage attacks on satellites.

Intrusion Detection and Prevention: The process of detecting and blocking cyber intrusions by leveraging signatures and machine-learning.

ITU Radio Regulations: Regulations by the International Telecommunication Union that govern the use of the radiofrequency spectrum and satellite orbits.

James Pavur: A PhD student at Oxford University who demonstrated how to hack a satellite using commonly available satellite television equipment.

JP 9102 Phase 1: A project announced by Defence in April 2023, which would deliver Australia's first sovereign-controlled satellite communication system over the Indo-Pacific Ocean regions.

JP 5408 Phase 3 (Platforms) Tranche 2: A project by the Australian Defence Department to enhance GPS on a range of ADF platforms.

KH-11: A type of satellite with a focus on electro-optical intelligence collection, launched by the United States in 1976.

Kessler Effect: A theory proposed by NASA scientist Donald Kessler, demonstrating that a 1cm object orbiting in space has the same kinetic energy as a hand grenade.

Killnet: A pro-Russian hacktivist group known for performing a distributed denial-of-service (DDoS) attack against SpaceX's Starlink system.

Kinetic Effects: Attacks resulting in physical damage to the satellites, such as missiles, rockets, lasers, and collisions.

Launch & Deployment: The process of launching and deploying military satellites is a complex and meticulously planned operation. It involves designing and developing the satellite, preparing it for launch, launching it from a spaceport, deploying it into the desired orbit, operating it while it is in orbit, and decommissioning it at the end of its operational life.

Low Earth Orbit (LEO): With altitudes ranging from 160 to 2,000 kilometers, orbit Earth rapidly, completing revolutions in 90 to 120 minutes.

Machine Learning (ML): ML is a subfield of artificial intelligence (AI) that uses algorithms trained on data sets to create self-learning models that are capable of predicting outcomes and classifying information without human intervention. It is one of the most common forms of artificial intelligence and often powers many of the digital goods and services we use every day.

Maxar Technologies: A company that provides high-resolution imaging to corporates and governments, including the US National Geospatial-Intelligence Agency.

MASINT (Measurement and Signature Intelligence): MASINT is defined as scientific and technical intelligence derived from the analysis of data obtained from sensing instruments for the purpose of identifying any distinctive features associated with the source, emitter or sender, to facilitate the latter's measurement and identification.

Medium Earth Orbit (MEO): Positioned between LEO and GEO, typically at altitudes of 2,000 to 36,000 kilometres, are commonly used for navigation systems like GPS.

Meteorology (MET): 1) The scientific study of the atmosphere that focuses on weather processes and forecasting. 2)The use of satellites to provide critical information about atmospheric conditions, which can significantly impact military operations.

Military Satellites: Satellites used for military operations, providing capabilities that are vital for national security.

NASA: The National Aeronautics and Space Administration, an independent agency of the U.S. federal government responsible for the civilian space program, as well as aeronautics and space research.

Miniaturization: The trend towards creating compact satellites, often referred to as CubeSats or NanoSats, which are cost-effective to launch and can be deployed in large numbers.

Moonpenny program: A program between the FVEY nations reported to intercept communications between foreign satellites.

NanoSats: A nanosatellite, also known as a CubeSat or NanoSat, typically weighs less than 10 kilograms and measures from 10 centimeters to 10 x 10 x 11.35 centimeters in size and often used for research, communication, and space exploration.

National Reconnaissance Office (NRO): A U.S. government agency responsible for the deployment of satellite technology.

National Security Agency (NSA): A U.S. government agency responsible for processing collected information.

National Space Mission for Earth Observation (NSMEO): A program announced by the Australian Government to design, construct, launch, and operate four new Earth observation satellites.

NAVWAR: Navigation Warfare, refers to measures to prevent adversaries from using GPS signals.

Non-Kinetic: Refers to actions that do not involve physical force but can still have significant effects. In this context, it refers to actions that can affect the operation of satellites without physically damaging them.

Non-Kinetic Effects: Attacks that do not result in physical damage to satellites, typically including cyber and electronic attacks.

Non-Kinetic Tracking and Monitoring: The process by which adversaries can track and monitor satellites and their transmissions, potentially gaining valuable information about military operations.

Observation (S&R): Surveillance and Reconnaissance – designed specifically for imaging Earth's surface at high resolution from space, it provides detailed images and video of potential targets on the ground.

Operation Fishbowl: A US operation involving the detonation of a nuclear warhead above the earth, demonstrating the potential for EMP damage in space.

Optus: An Australian telecommunications company that, in collaboration with SpaceX, plans to roll out SMS from late 2024, with voice and data also on the horizon from late 2025.

Orbit: What type of orbit is the satellite operating in, see LEO, GEO etc.

Orbital Jamming: A form of electronic attack where a beam of contradictory signals is directed towards a satellite, overriding legitimate signals and blocking their transmission.

Orion Satellites: Also known as Mentor or Advanced Orion, these are a class of United States spy satellites developed by the National Reconnaissance Office (NRO) and operated by the NSA.

Outer Space Treaty: The foundational legal instrument governing the use of space. It establishes several key principles including peaceful purposes, freedom of exploration and use, responsibility and liability, and international cooperation.

Palapa series of satellites: Launched by NASA in 1977 on behalf of Indonesia, these satellites were used for both public and defence purposes.

Payload: Payload module will vary depending upon the satellites tasking, for some highly specialized satellites the payload is fully integrated into the satellite's form.

Physical Attacks: The use of anti-satellite weapons (ASATs) to physically damage or destroy satellites.

Physical Protection: In some cases, using military force to protect satellites. This could involve deploying anti-satellite weapons to deter or counter attacks.

Polar Orbit (PO): A path that takes satellites over the Earth's poles, allowing them to observe the entire planet over the course of several orbits.

Position, Navigation and Timing (PNT): The use of satellites, such as those in the Global Positioning System (GPS), to provide accurate positioning and timing information.

Precise Positioning Service (PPS): A service primarily intended for use by the US Department of Defence and selected allies, providing location information of an object to within 90 centimeters.

Precise Positioning Service (PPS): An extremely accurate military positioning, velocity and timing service which is available on a continuous, worldwide basis to authorized users.

Project Azorian: A Central Intelligence Agency project that raised part of a sunken Soviet submarine.

Project Bold Orion: A US project developing anti-satellite missile technology.

Project Larswood: A project by Australia reported to have been monitoring Indonesia SATCOM since 1979.

Protection and Defensive Measures: Measures taken to protect military satellites from potential threats. This could include physical protection measures, cybersecurity measures, and more.

Quantum Technology: In the context of quantum computing, it uses key principles of quantum mechanics such as superposition and entanglement. Superposition allows quantum bits (or qubits) to exist in multiple states at once, rather than just 0 or 1 as in classical bits. Entanglement allows qubits that are entangled to be linked such that the state of one can depend on the state of another, no matter the distance between them. These principles enable quantum computers to process a high number of possibilities simultaneously, providing the potential for tremendous computational speed and capacity and highly secure cryptographic solutions such as voice and data communications.

Radiocommunications Act 1992: An Australian law that mandates that all radiocommunications devices' operation, including Earth stations and space stations on satellites, be authorized by a license issued by the Australian Communications and Media Authority (ACMA).

Resilient Architectures: The design of satellites to be resilient, meaning they can withstand attacks and continue to function. This can involve using redundant systems, so if one satellite is disabled, others can take over its functions.

SATCOM: Short for satellite communication, it refers to the use of artificial satellites to provide communication links between various points on Earth.

Scanning: A process for identifying, attacking, and stealing information from a targeted host.

Secure Communication Protocols and Encryption: Establishing secure communication protocols and implementing end-to-end encryption for data transmission as fundamental countermeasures. This ensures that even if data is intercepted, it cannot be understood.

SIGINT (Signals Intelligence): SIGINT is the act and field of intelligence-gathering by interception of signals, whether communications between people (communications intelligence — abbreviated to COMINT) or from electronic signals not directly used in communication (electronic intelligence —abbreviated to ELINT).

Skykraft and Airservices Australia: Canberra-based organizations that are launching a constellation of 200 satellites over two years to improve flight safety and communication.

Sovereign Launch Capability: The ability of a nation to launch satellites into space using its own resources and technology. Australia is developing its own sovereign launch capabilities.

Space Debris: Accidental collisions with space debris can damage or destroy satellites.

Space Domain Awareness: Monitoring space closely to detect potential threats as early as possible. This includes tracking space debris and monitoring the activities of other countries in space.

Space Industry Responsive Intelligent Thermal (SpIRIT) satellite: A nano satellite launched from Vandenberg Space Force Base in California, USA in 2023.

Space Machines Company: A Sydney-based company that created a device designed to repair and refuel other space infrastructure. It also tests state-of-the-art printed solar cells developed by the CSIRO.

Standard Positioning Service (SPS): The positioning and timing service that the GPS provides to all users on a continuous, worldwide basis with no direct charge.

Supply Chain Risk Management: A program to protect against malware inserted into parts and modules.

Synthetic Aperture Radar (SAR): A form of radar that is used to create two-dimensional images or three-dimensional reconstructions of objects, such as landscapes.

Terrestrial jamming: A form of electronic attack where rogue frequencies are directed to ground-based targets, distorting their transmission.

Tracking, Monitoring, and Capturing: The process of observing and recording the behaviour or output of satellites or taking control of them.

United State Space Surveillance Network (USSSN): A system that detects, tracks, catalogues, and identifies artificial objects orbiting Earth.

Satellite: An object in space that orbits or circles around a bigger object. In this context, it refers to man-made equipment that orbits around the earth.

Threat Information Sharing: Sharing threat information with private sector partners, such as the dissemination of critical space domain awareness and cybersecurity threat information at multiple classification levels.

US Space Force: A branch of the U.S. armed forces tasked with space warfare VSAT (Very Small Aperture Terminal): A satellite system commonly used by internet cafés and foreign governments in the Middle East to send and receive communications and data.

Wagner Group: A group that caused a temporary outage at Russian Internet provider Dozor-Teleport by attacking numerous satellite ground terminals by uploading malware.

Wideband Global SATCOM System (WGS): A high-capacity satellite communications system delivered by a constellation of 10 satellites in geostationary orbit, providing very high-speed broadband used by the United States Department of Defense (DoD), Canadian Department of National Defence (DND), and the Australian Department of Defence.

WRESAT-1: Australia's first satellite, built by DSTO (now DSTG) and launched from Woomera Rocket Range in 1967. It completed 642 orbits.