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THE NETWORK EFFECT

Strategising Connectivity at Sea for Maximum Impact

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RESEARCH PROGRAMME

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Terrestrial and satellite connectivity technologies have already helped shipping to advance its digital capabilities at sea. As technologies such as AI and big data analytics gather momentum, the demand for connectivity is exponentially growing.

FOREWORD

BEN PALMER, PRESIDENT, INMARSAT MARITIME

The development of satellite connectivity in recent decades has helped to propel shipping into the digital era. Yet as the maritime regulatory landscape evolves, and shipowners place ever-greater emphasis on crew welfare, decarbonisation and digitalisation, demand for connectivity is soaring.

Advanced digital technologies hold the power to optimise and decarbonise shipping operations, but harnessing this potential relies on a strategic approach to connectivity.

According to a recent Inmarsat study, maritime data usage associated with shipboard business applications increased by 131% from June 2021 to June 2022, with crew-related data consumption growing by 149% in the same time frame.

Data and connectivity are clearly critical to the shipping industry's ability to overcome its current challenges and achieve its long-term ambitions, but simply purchasing bandwidth is no longer enough.

Without the right communications infrastructure to support them, digital technologies cannot deliver the many benefits they promise in terms of business optimisation, decarbonisation, and seafarer welfare.

It is against this background that maritime innovation consultancy Thetius compiled the enclosed report. With focus on the current and future trajectories of maritime connectivity, The Network Effect: Strategising Connectivity at Sea for Maximum Impact describes the importance of taking a strategic approach to building connectivity that supports the industry's present and emerging needs.

By joining the dots between business goals and connectivity options, operators gain access to a host of benefits including opportunities to optimise and drive efficiency while reducing running costs and improving profit margins; the ability to attract and retain talented crew; and the capacity to future-proof operations and build in competitive advantages.

Applied to IT and the business network, a robust connectivity strategy provides a foundation for tools and services that support decarbonisation initiatives, facilitate trade, and enable voyage and port-call optimisation as well as condition monitoring and condition-based maintenance. With regard to the crew network, the right strategy enhances seafarer health, well-being, safety, and training, in turn helping shipping companies to recruit, nurture, and retain the most-talented seafarers. Where operational technology and the critical infrastructure network are concerned, an effective connectivity framework enables remote services including equipment intervention, surveys, pilotage, and telemedicine.

Ultimately, a good connectivity strategy relies on a clear understanding of the company's business goals, the technologies needed to attain those goals, and any additional influencing factors such as resource availability and investment requirements. In that sense shipping is no different to any other industry: collecting, collating, analysis and harnessing the value of data relies on resilient, reliable, secure, globally available connectivity services. It is also critical to recognise that implementing a connectivity strategy is a continuous and iterative process that requires constant monitoring, frequent reassessment, and regular feedback from internal and external stakeholders. As this report makes clear, this is both necessary and highly valuable to modern shipping operations, both in terms of driving competitive advantage and addressing decarbonisation goals.

INTRODUCTION

Ships, shipping companies and cargo owners are becoming increasingly interconnected. Digital technologies are becoming an established feature of the present and a key element of the future of shipping.

If these technologies are to make the required impact, a strategic approach to connectivity is also required.

Connectivity provides oxygen to the digital ecosystem that will drive efficiency and decarbonisation at sea.

Connectivity provides oxygen to the digital ecosystem that will drive efficiency and decarbonisation at sea. This report examines what it takes to build a connectivity strategy fit to power a new digital era in the global shipping industry.

Optimising and decarbonising ships to meet the demands of a changing world requires the onboarding of a range of technologies. Capabilities such as AI–enhanced voyage management, IoT–backed condition-based maintenance (CBM), and automated emissions reporting, demand significant investments of time and money from operators and a sustained focus on long-term goals. But if these technologies are to make the required impact, a strategic approach to connectivity is also required.

It was back in 1973 that the IMO set about establishing a new maritime communication system based on satellite technology. By 1976, a convention on an International Maritime Satellite Organization was adopted, and so Inmarsat was born.

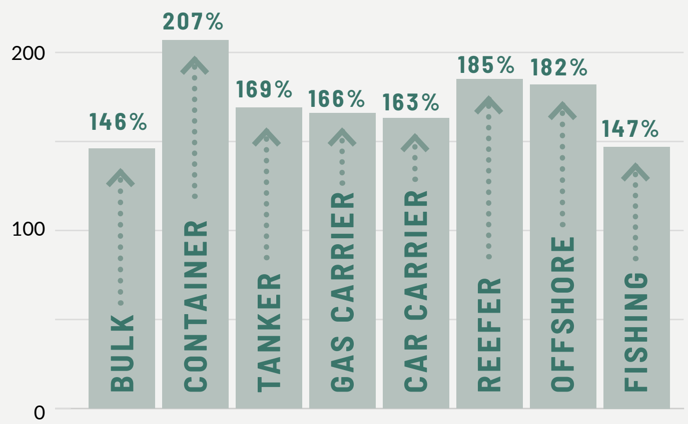
Over five decades of development and improvement have passed in satellite connectivity since then, and there are now over 5400 satellites orbiting the earth.[1] Systems range in type and altitude, offering options on speeds and capabilities. This space segment is increasingly complemented by a growing terrestrial segment, bringing coastal cellular networks such as 5G into the maritime domain via tandem or hybridised network packages.[2]

As these capabilities develop, the focus shifts more towards crew and cargo. The challenge of maintaining an efficient system of ocean transport that attracts talented and dedicated crew members requires new thinking and innovation. Challenges as complicated as globalised trade and as pressing as climate change, also require real ambition.

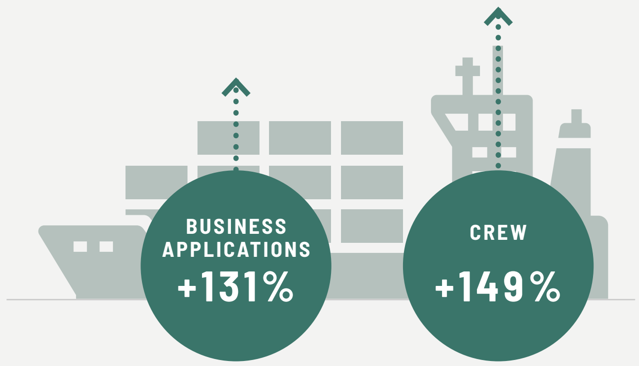
1 Union of Concerned Scientists (2022) UCS Satellite Database Retrieved from https://www.ucsusa.org/resources/satellite-database

2 The International Telecommunication Union (2019) Terrestrial wireless communications Retrieved from https://www.itu.int/en/itunews/Documents/2019/2019-04/2019_ITUNews04-en.pdf

DATA USAGE TRENDS
JUNE 2021 VS. JUNE 2022



WHAT IS DRIVING THIS DEMAND?



- **Voyage optimisation / Decarbonisation**
- **Remote opertations** (e.g. Audit, Telemedicine, CCTV, Safety & Security)
- **Crew welfare and connectivity**

Terrestrial and satellite connective technologies have already helped shipping advance digital capability at sea.

The rate of progress in digital technology in recent times has hailed a new industrial age. Terrestrial and satellite connective technologies have already helped shipping advance digital capability at sea, most rapidly since the early iterations of the global maritime distress and safety system (GMDSS) in the 1980s. But as technologies such as AI and big data analytics gather momentum, the demand for connectivity is exponentially growing.

An internal study conducted by Inmarsat shows that growth in data usage at sea has been climbing dramatically in recent years. Year-on-year growth in Inmarsat satellite data usage between June 2021 and June 2022 increased by up to 207% in container shipping. The bulk sector, which was slowest growing over the period, experienced a 146% increase. While business applications accounted for a 131% increase in data usage across all vessel types, the biggest increases were found in crew data usage which rose by 149%.

In this report, we look at the current and future trajectories of maritime connectivity and demonstrate that by taking a strategic approach that is fit for present and evolving needs, shipping can better meet its current and future business goals.

There is no doubt that expectations and administrative burdens placed on seafarers have also increased in recent decades. Captain Pradeep Chawla, Managing Director QHSE and Training at Anglo-Eastern Shipmanagement Ltd. noted in an interview with Thetius, *"The number of tasks that a seafarer has to do today has risen many times over in the last two decades. I came ashore in 1992, but when I was at sea, there were perhaps 6 or 7,000 pages of regulations pertaining to our operations in total. Today, we are dealing with more than 20,000."*

He continues, *"For me, the challenge is this: how do seafarers work safely and efficiently with the amount of tasks that are presently having to be done? One of the things Anglo-Eastern is trying to do is to reduce the administrative burden of filling in multiple forms and duplicating effort. Digitalisation and connectivity are key to helping us do that."*

The human element is just one piece of a larger puzzle. Data and connectivity are the catalysts needed to accelerate digitalisation in shipping in all directions. Without the correct communications infrastructure to enable them, digital technologies can't operate and won't improve the businesses that invest in them. As Chris Sepp, Vice President of IT at Atlas Corp. (Seaspan) notes, *"A modern vessel can harvest 800-900 data points per second if you allow it to. Even if you only measure and collect data four times per minute, that's a lot of data points per vessel over a 24-hour period."*

In this report, we look at the current and future trajectories of maritime connectivity and demonstrate that by taking a strategic approach that is fit for present and evolving needs, shipping can better meet its current and future business goals. As we will see, in this rapidly advancing era of technology-based competition in shipping, buying bandwidth is no longer enough.
Those that get ahead in such market conditions will do so by realising how the transition will play out in the coming years, putting emphasis on an effective connectivity strategy that will enable their ambitions and power growth.

Data and connectivity are the catalysts needed to accelerate digitalisation in shipping in all directions.

WHY TAKE A STRATEGIC APPROACH TO CONNECTIVITY?

Satellite connectivity has moved beyond constrained bandwidths and high access costs. As capability has developed, the industry can look forward to high–performing connectivity becoming an integral part of the basic infrastructure and derestrict tool and platform development.

High performance data exchange enables shipping companies to treat their ocean-going fleets as remote office locations and further integrate them into their business networks. Cloud computing has revolutionised co-working, collaboration, and consolidation of processes across multiple domains – why not ships too?

Vice President of IT at Atlas Corp. (Seaspan), Chris Sepp, describes some of the unique challenges faced by larger fleets; “*If we can overcome the view that maritime connectivity will always be bandwidth constrained, we are able to look beyond digital solutions that are not scalable for companies that have 200+ vessels, like us.*”

High performance data exchange enables shipping companies to treat their ocean-going fleets as remote office locations and further integrate them into their business networks.

Shifting mindsets away from the belief that unlimited connectivity at sea is restrictive or prohibitively expensive opens new possibilities for business improvement. Mr. Sepp continues, "*At Seaspan, we believe in pursuing a strategy where the vessel is no different from a remote office, where you don't need to tell people how much they should or shouldn't be using the internet. As a side-effect of that, you end up with the material readiness for IoT, big data, OT remote systems and all the bells and whistles required for emissions reduction by default.*"

Today, proven and reliable Geosynchronous Equatorial Orbit (GEO) satellites work in partnership with low latency Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) satellites to provide connectivity that is tailorable to its application. Increasingly, these services can be offered in hybrid form with different satellite arrays and terrestrial components within a single integrated package, bringing quality, reliability, and performance to berth-to-berth connectivity for today's more sophisticated and data-hungry vessels.

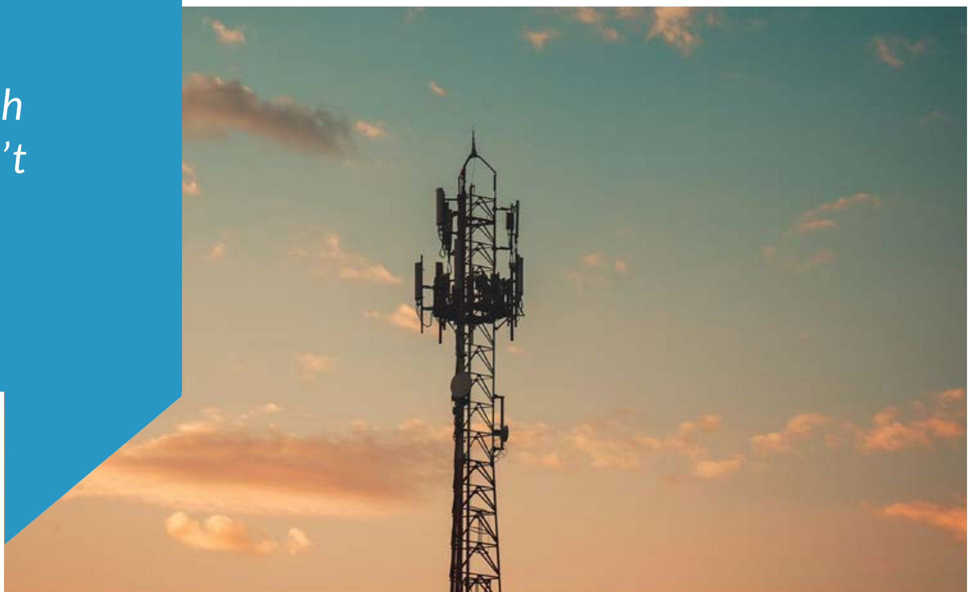
> *"At Seaspan, we believe in pursuing a strategy where the vessel is no different from a remote office, where you don't need to tell people how much they should or shouldn't be using the internet."*
>
> **Chris Sepp, Vice President of IT at Atlas Corp (Seaspan)**

WHAT CAN A CONNECTIVITY STRATEGY ENABLE?

For ship operators, achieving overall business aims means becoming increasingly reliant on technology. This requires joining the dots between business goals and the connectivity options that are available. Doing this effectively will allow operators:

- Control over connectivity requirements
- The ability to attract and retain talented crew
- Fleet benchmarking
- Opportunities to optimise and drive efficiency
- Control data and gain insights
- Reduce running costs and improve profit margins
- Future proof operations and build-in competitive advantages

Here we explore the tools and services that are enabled by an effective connectivity strategy across business IT, crew, and operational technology (OT) networks.



"Over the last 30 years, asset owners have placed a lot of attention on optimising individual assets in a supply chain. But that is not the same as having an optimised supply chain. What tends to happen is that inefficiencies get pushed towards the cheapest ton-mile assets in the chain, because that's where, at least from an economic perspective, they hurt the least. In our case, our vessels are the cheapest assets in the chain, so the inefficiency gets pushed to us, usually in the form of long waiting times at anchor before entering port."

Benne Engelen, CIO at Anthony Veder

INFORMATION TECHNOLOGY (IT) AND THE BUSINESS NETWORK

OPTIMISATION

Voyage optimisation

Considerable reductions in carbon emissions, efficiency, and profitability are enabled by today's slew of voyage optimisation platforms such as those offered by Yxney Maritime, Theyr, StormGeo and NAPA. These tools calculate and propose routes that can be given multiple objectives depending on individual circumstances. Many of these solutions gather data directly from vessels and then combine it with external data sets to produce their outputs.

Port Call optimisation

An optimal port call relies on the timely sharing of information between trade and supply chain partners to streamline vessel logistics and cargo work. This streamlining can make voyages more profitable, cargo owners more satisfied with their transport service, and positively influence safety, efficiency, and environmental outcomes.

Data sharing and improved collaboration are pivotal here. Innovators such as PortXchange, Intelligent Cargo Systems, and Awake AI, provide new opportunities to optimise cargo operations. Awake AI and PortXChange offer digital collaboration platforms that connect key stakeholders in the supply chain to improve and support transparency. Intelligent Cargo Systems meanwhile focuses on measuring and improving the productivity of container vessels at the berth by providing officers with more accurate cargo completion times and sharing that information with partners.

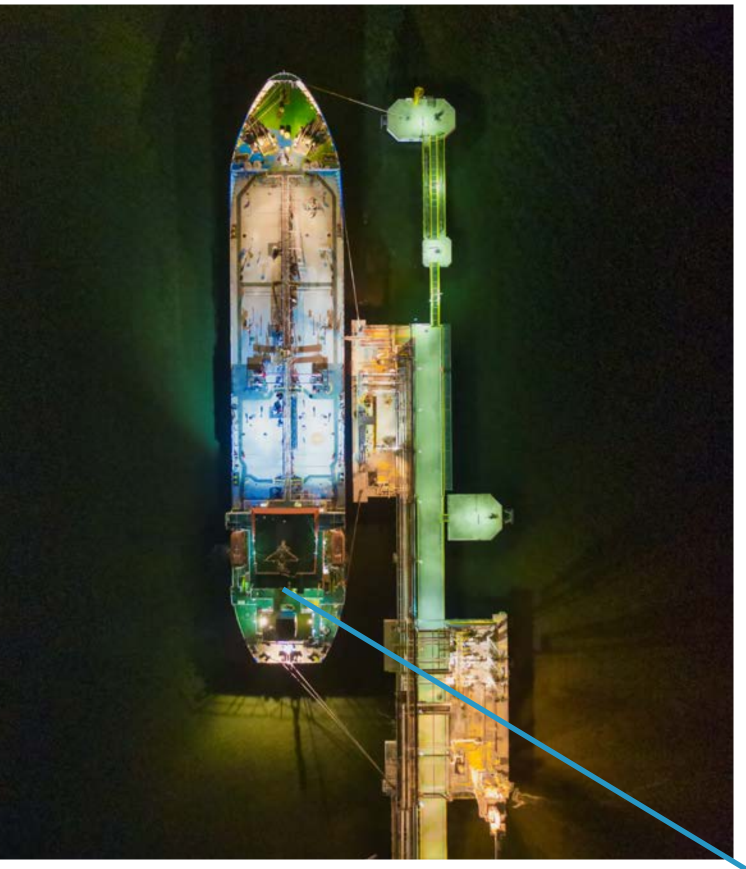
Benne Engelen, CIO at Anthony Veder, believes that port connectivity is vital. He told Thetius that, *"Working with the same information at the same time, with all the stakeholders in the chain, really allows us to make better decisions and annihilate port waiting times. Obviously, digital technology can be of great value in doing that."*

DECARBONISATION

Research suggests that potential reductions in carbon emissions of up to 38% are possible by digitalising ship operations alone.[3] With the IMO adopting targets to reduce the carbon intensity of all ships by 40% by 2030, there is intensifying interest around tools that offer a route to net-zero.[4] Methods that reduce fuel consumption ultimately decrease emissions. Digital twins and artificial intelligence that can collate data and inform decision making can also have a positive effect. MO4, a smart solution provider, is actively engaged in a 10-year contract with an offshore fleet to provide their services for this purpose.

"A key component of our connectivity strategy right now is bringing machinery analytics onboard with a view to rolling out condition-based monitoring of our ships."

Capt. Pradeep Chawla, Managing Director QHSE and Training at Anglo-Eastern Ship Management Ltd.



CONDITION MONITORING AND CONDITION-BASED MAINTENANCE

Predicting failures before they occur is challenging but the benefits of it are considerable. Methods such as vibration and lubricant analysis to HD shock pulse monitoring, core sensor technology and data analytics, are enabling safer and more cost-effective approaches to planned maintenance. Kongsberg Maritime, Ritec Marine and Pruftechnik are amongst many others that are being recognised in this space.

3 Thetius (2022) The Optimal Route Retrieved from https://thetius.com/the-optimal-route/

4 IMO (2021) Cutting GHG emissions from shipping- 10 years of mandatory rules Retrieved from https://www.imo.org/en/MediaCentre/PressBriefings/pages/DecadeOfGHGAction.aspx

TRADE FACILITATION

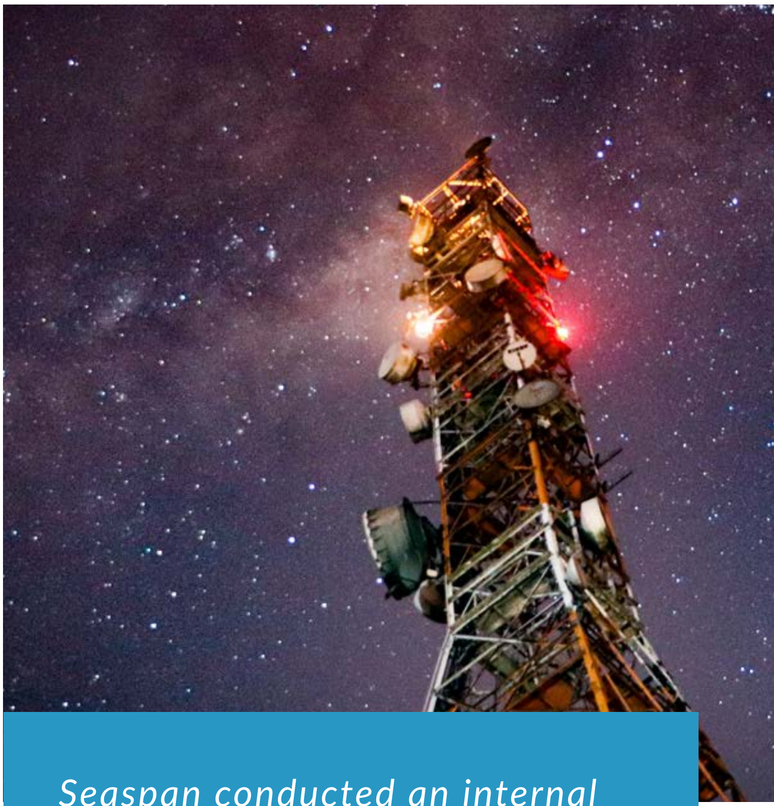
Reporting

The EU MRV (monitoring, reporting and verification) and IMO DCS (Data collection system for fuel oil consumption) are two in a growing digital reporting regime. Importantly, they require external verification to ensure that data is complete and correct and that the reporting company is acting in accordance with the specified requirements.

At the company level, noon reports also place increasingly unnecessary manual data entry requirements on busy officers. Seaspan conducted an internal study across their fleet in 2021 and concluded that 78% of all data points that were manually entered into noon reports are actually available digitally. Their VP of IT, Chris Sepp said, *“where you have a decent Automated Manifest System, you actually can systemise that process relatively easily with the right connectivity.”*

Digital document exchange

The number of documents that are exchanged digitally is increasing in line with the wider digitalisation of the supply chain. Organisations are openly committing to and collaborating on digital document packs. The Electronic Bill of Lading (EBL) is one high-profile example. The importance of a connectivity strategy here is vital as ‘the secure transfer of e-bills is needed to combat the increased sophistication of cybersecurity threats, which is one of the main areas of resistance to digitalisation’ according to international maritime law firm Hill Dickinson.[5]



Seaspan conducted an internal study across their fleet in 2021 and concluded that 78% of all data points that were manually entered into noon reports are actually available digitally.

Tracking

The requirement and desire to improve supply chain transparency and efficiency will be a driving force behind the increase in monitoring and tracking solutions. In Q1 2022, Hapag-Lloyd announced that they would be the first shipping company in the world to equip all their standard containers with real-time tracking devices. There is little doubt in the liner trades that Hapag-Lloyd's success here would precipitate a much wider adoption across the sector.

5 R Allingham, E Elliott (2022) Hill Dickinson- Digitalisation of bills of lading Retrieved from https://www.hilldickinson.com/insights/articles/digitalisation-bills-lading

CREW NETWORK

CREW WELFARE

A recent update to the Maritime Labour Convention (MLC) has given seafarers the right to mandatory internet access whilst at sea. The benefits of improving seafarer health and wellbeing through connectivity are becoming increasingly clear. In 2022, Thetius surveyed over 200 maritime professionals and discovered something surprising. 33% of seafarers chose access to digital technology as the most important factor when considering working for a new employer - above pay and leave entitlement.[6] Connectivity offers a lifeline in helping to ease social isolation, improve mental health through social interaction and enhance physical health through exercise apps and programs.

Internet-enabled process automation also provides safety improvements at sea. A recent Thetius study found that 78% of seafarers regularly feel fatigued at work. 87% of the same study group believed that digital transformation would have a beneficial effect on crew retention, indicating wider benefits towards building and maintaining experienced crew.

87% of the [Thetius study] group believed that digital transformation would have a beneficial effect on crew retention, indicating wider benefits towards building and maintaining experienced crew.

"The problem is that crews are getting harder to find and good crews can go anywhere. If you want to attract and keep those crew, you have to do something other than good wages. We recognised very early on that good quality internet onboard our ships was going to be very important to attracting and retaining good quality crew. We are always looking at what it is that our crews want and how we can make their lives better. The ultimate goal is to provide them with the same level of connectivity that they get at home."

Neil Giles, Chief Technology Officer at Petredec Pte. Limited.

CREW TRAINING

The delivery of crew training, not only legally required but competency focused, has changed dramatically during the global pandemic. This style of training and use of remote crew learning services has increased in frequency, with many choosing to focus on remote options as opposed to traditional face-to-face methods. Not only does this reduce the financial costs of training, but it also allows for sessions to be conducted both onshore and offshore. The Canadian Coast Guard are an advocate for this method of blended learning. At the start of 2022, a multi-year contract extension with Marine Learning Systems (MLS) was announced that will see the continuation of their partnership for online training.

6 Inmarsat (2022). Seafarers in the Digital Age Report. Available at https://www.inmarsat.com/en/insights/maritime/2022/seafarer-human-element-digital-transformation.html

OPERATIONAL TECHNOLOGY (OT) AND THE CRITICAL INFRASTRUCTURE NETWORK

REMOTE EQUIPMENT INTERVENTION

Allied with condition monitoring and condition-based maintenance, the ability to support onboard crew remotely during troubleshooting and repairs is a compelling concept for many ship owners. This relies on the ability to connect at short notice and irrespective of geographic location. This type of connection benefits from a reliable, high-quality pipeline that provides uninterrupted video and audio streaming to allow two-way communications between onboard and shoreside technicians. This reduces the financial risk associated with OEM interventions, including logistics, diversions, and delays.

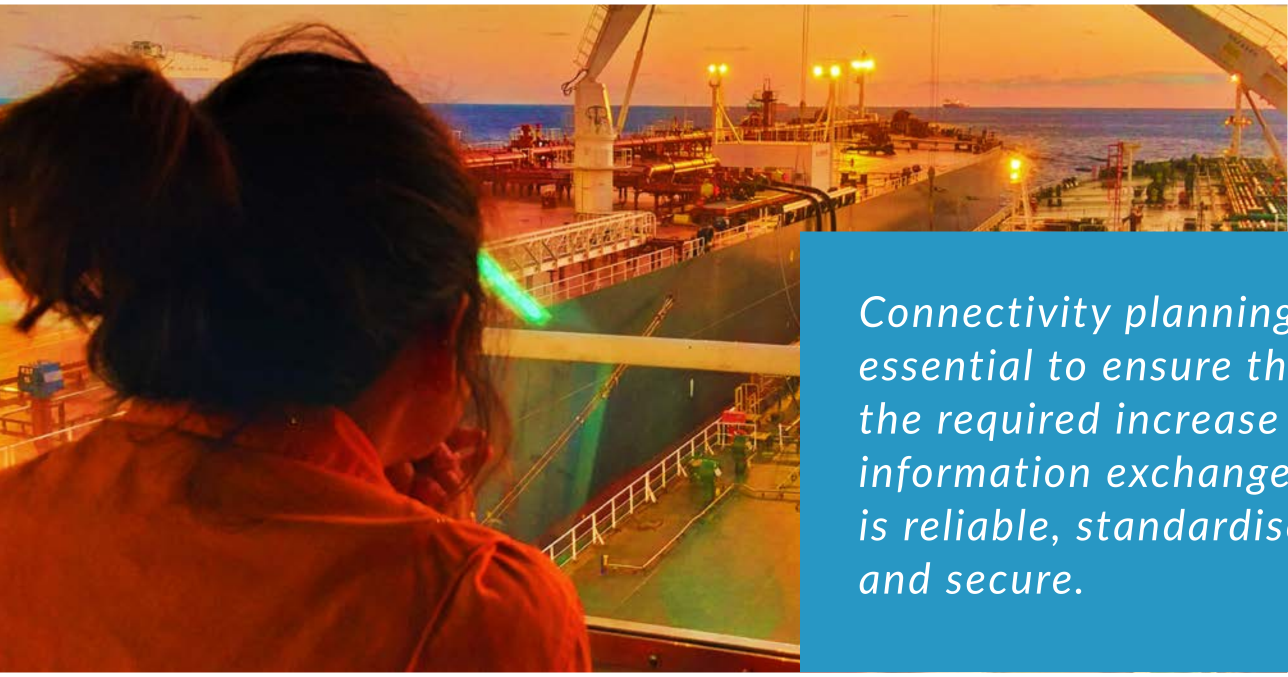
Chris Sepp, Vice President of IT at Seaspan puts it like this, "*All of our ships are deployed to generate revenue. We don't have the luxury of having regular physical access to them in drydock etc., so the majority of shoreside interventions need to be performed remotely.*"

> *Most leading classification societies now facilitate remote surveys in full or in part and in response.*

REMOTE SURVEY

Convention has required surveyors to physically attend vessels to complete their examination. Increasingly, remote surveys are being facilitated by crews using tablets and other portable digital devices. Over much of the early stage, remote surveys have generally been carried out using an internet connection that is not sufficient to support live video streaming for the entire survey. However, at the discretion of the surveyor, pre-recorded videos and images are sometimes used. Most leading classification societies now facilitate remote surveys in full or in part and in response, the International Association of Classification Societies (IACS) released unified guidance in March 2022.[7]

7 IACS (March 2022), UR-Z29 Remote Classification Surveys. Retrieved from https://iacs.org.uk/media/8890/ur-z29.pdf



Connectivity planning is essential to ensure that the required increase in information exchange is reliable, standardised and secure.

REMOTE PILOTAGE

A reform of the Pilotage Act in 2019 allowed pilotage to be provided to a vessel remotely for the first time. Organisations like FinnPilot and DanPilot have been pioneering and several trials have led to significant advancements in recent times. State owned authority FinnPilot completed trials in 2022 and are expecting to apply for their first remote pilotage permit in 2025. Estimates have predicted that remote pilotage has the potential to contribute an additional €4mn profit for the average port pilotage service.[8] Connectivity planning is essential to ensure that the required increase in information exchange is reliable, standardised and secure.[9]

EMERGENCY MANAGEMENT

The objective of the International Safety Management code (ISM) is to ensure safety at sea, prevent human injury or loss of life, and minimise adverse environmental impacts.[10] From services such as Lloyd's Registers Ship Emergency Response Service (SERS), to contacting state coastguard rescue services, there is a growing range of tools that digitally enhance and enable emergency management and response.

The need for a reliable and stable connection during an incident is self-evident. The connectivity strategy should look to build a network that can provide stable and prioritised bandwidth when required. The IMO also considers telemedicine an integral part of maritime resilience. Focus is increasingly opening up to preventive care and ongoing care management. This is increasing the connectivity requirement for video calls and even augmented reality medical support.

8 Wärtsilä (2019) Pilotage Digitalisation. How remote is the remote pilotage? Retrieved from https://www.wartsila.com/insights/article/pilotage-digitalisation-how-remote-is-the-remote-pilotage

9 C Eason (2022) Remote Pilotage: The future in Finland Retrieved from https://fathom.world/elementor-20201/

10 IMO (2010) ISM Code 2010 Edition Retrieved from https://www.imo.org

A NEW APPROACH TO MARITIME CONNECTIVITY

Staying connected improves the lives of seafarers and offshore workers. It also provides a pathway for innovators to bring new solutions to maritime problems.

Software developers and OEMs are keen to make their solutions accessible to remote users. Satellite technology plays a vital role by integrating these solutions at sea. In the years ahead, this role will become increasingly important.

Data management will grow alongside the industry's push for digitalisation. It will always be the foundational component of digital technology. Real-time data processing, scalability, and harmonisation remain watchwords for a digitalised shipping industry. It's important that digital systems offered to ship operators can be onboarded and used easily. This is best achieved by supporting shared functions and identifying common data requirements across applications.

This requires the gathering and sharing of large amounts of data. Reducing friction in exchange and automating more of the process is of paramount importance. Satellite connectivity needs to do more for its users, while asking less of them in return. The shipping industry doesn't need new complications; it just needs new capabilities.

"The current pace and scale of technology development is worth consideration. In the mid-90s, you could hang back a little bit to see if this new 'email' concept was something for you or not. But now, there are too many technologies to focus on in one go and they're developing too fast. If you delay, then you're playing a catch-up game at best, and more likely to become obsolete."

Benne Engelen, CIO at Anthony Veder

Attitudes to data sharing and collaboration among maritime trade partners is shifting. Demand for data exchange technology is growing as a result. Recent sampling showed that 2 in 5 signals on the Thetius Intelligence Platform related to alliances formed within data management. This figure is high when compared to other signal types captured.[11]

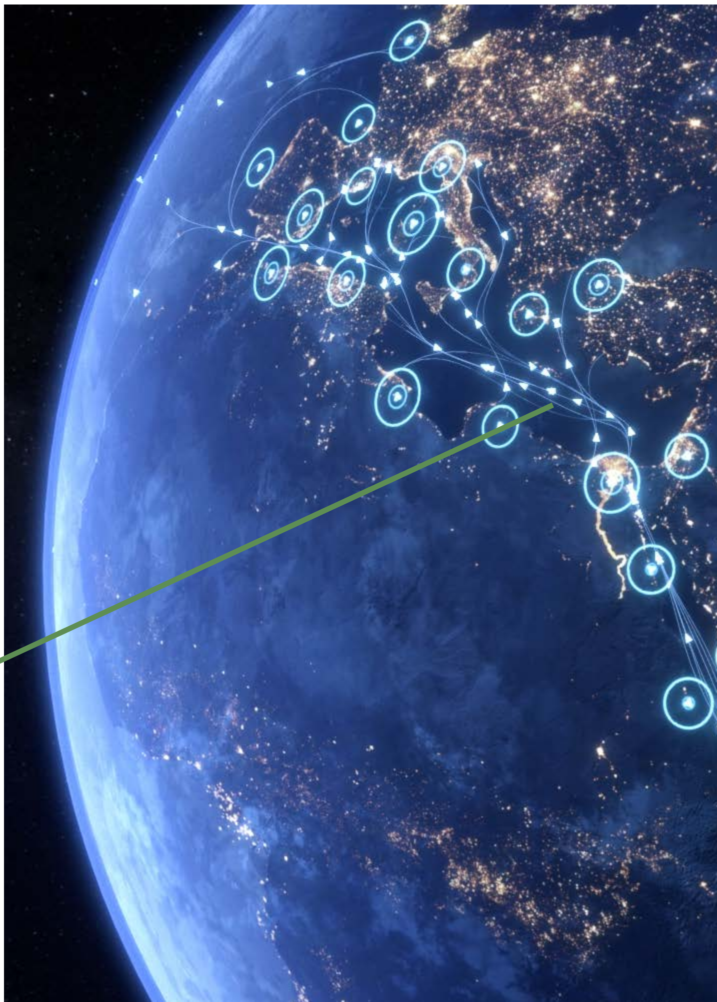
11 Analysis by Thetius, Captured data as of 28 September 2022 from the Thetius Intelligence Platform

“We generate a lot more data today than we did a few years ago, and we do a lot more with that data. Satellite communications were previously a peripheral element of our fleet operations but are now becoming a central component – in terms of both crew welfare and data collection and transfer.”

Florian Liebetrau, Director IT–Marine and Maritime Operations at Hapag-Lloyd

Technologies like Software-Defined Wide Area Network (SD-WAN), bring a wealth of connected capabilities for mobility businesses globally. SD-WAN offers a network of networks to route data intelligently and dynamically via the most efficient and relevant paths, depending on the nature of the information. For example, for Inmarsat users, multiple pathways will be available via its multi-dimensional communications network ORCHESTRA, from existing networks in Ka-band with Fleet Xpress or in L-band via ELERA, as well as in the future via 5G terrestrial connectivity and LEO satellites. By combining multiple networks, SD-WAN delivers excellent customer experience through highly secure, ultra-reliable global connectivity, which is crucial when serving mobility customers.

Shipping will need to connect and exchange more in the years ahead. It's clear that, in port or at sea, a ship can no longer become invisible. But, while networks are becoming more sophisticated to meet this demand, usability cannot suffer. The gold standard in satellite connectivity is moving rapidly towards simplifying the user experience.



WHAT ARE THE OPTIONS?

UNDERSTANDING THE PRESENT AND FUTURE OF MARITIME CONNECTIVITY

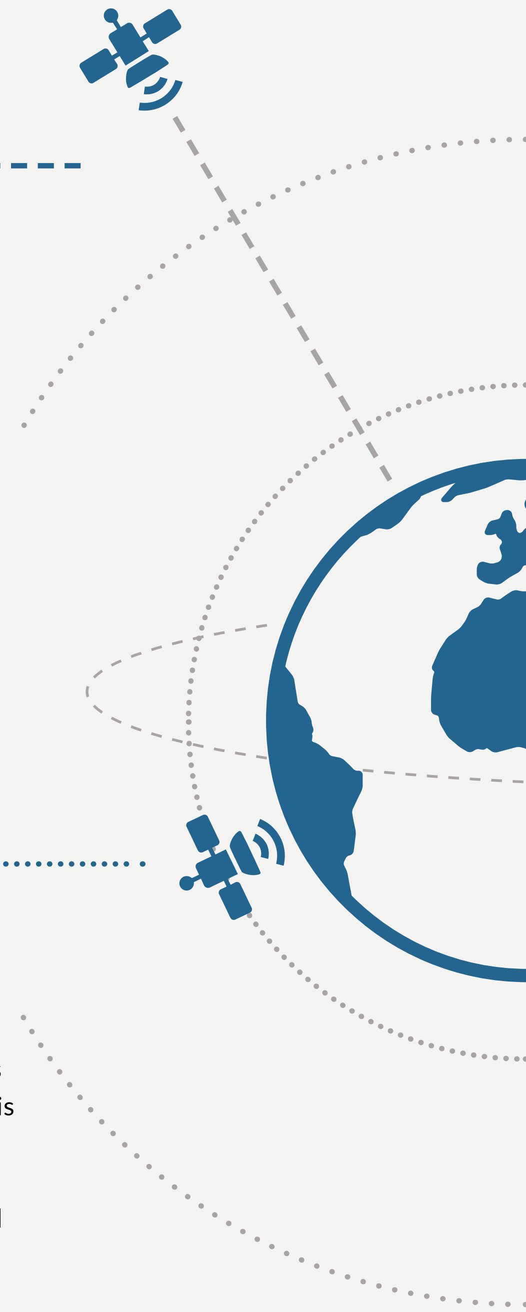
Once the business understands its objectives and identifies the digital tools and capabilities it needs to achieve them, it is time to find a suitable range of communication services that will deliver the desired outcomes. Working with a trusted and experienced provider is the best way of determining which services will be most suited, but it helps to have a good understanding of the options available.

* For detailed technical overview, **see Satellite Technology Supplement starting on page 38.**

Working with a trusted and experienced provider is the best way of determining which services will be most suited

A BRIEF GUIDE TO SATELLITE TECHNOLOGY: SATELLITE ORBITS

Satellites are designed to maintain one of several orbit profiles around Earth. This orbit is determined by balancing velocity and trajectory with the earth's gravity and the orbit achieved influences the capabilities and coverage expected from the satellite.[12]



GEOSTATIONARY ORBIT (GEO)

GEO or 'geostationary' satellites complete one orbit in 24 hours. Because this precisely matches the earth's rotation, the satellite maintains a fixed position relative to the earth's surface, at an altitude of approximately 36,000 km. Their high altitude and stationary nature allow them to offer stable audio, video, and data services over a wide footprint. Using a system of three geostationary satellites can allow users to cover almost any location on the planet.

This setup can allow an antenna on Earth to be fixed and aimed at the satellite. It can also be utilised for weather monitoring satellites, which keep track of a particular region to see how weather patterns develop over time. These fixed antenna sites can be used by both senders and receivers with no modifications usually required. As such, they offer a high level of reliability and practicality.

LOW EARTH ORBIT (LEO)

Satellites on the Low Earth orbit (LEO) are relatively close to the Earth's surface. They are normally at an altitude of less than 1,000 km but could be as low as 160 km above Earth.

LEO is useful for several reasons, but mostly because of its close proximity to Earth. Satellites operating in this orbit are most frequently utilised for imaging since being close to the surface enables it to capture images with a higher resolution. The reduced altitude can also decrease atmospheric interference by remaining below areas of electromagnetic noise, such as the 'Van Allen Belt'.

However, satellites in LEO move at a fast pace across the sky and are difficult for ground stations to acquire and track. To provide for continual coverage, LEO communication satellites frequently operate in constellations. This enables them to simultaneously cover a large portion of Earth when working together and reduces the delay in signal transmissions by spreading processing and exchange hardware among a number of satellites, thus reducing demand load on individual satellites.

12 European Space Agency (2020) Types of Orbits, retrieved from https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits

MEDIUM EARTH ORBIT (MEO)

A Medium Earth Orbit (MEO) will orbit between 6,000 and 20,000 kilometres above the surface of the Earth. Between LEO and GEO, a wide variety of orbits are classified under MEO. The system only requires twelve satellites, which is more than a GEO system but considerably less than a LEO system, averaging orbits of around 10,000 km.

In terms of functionality, they closely resemble LEO satellites. These satellites move more slowly in relation to a fixed point on earth, allowing for easier acquisition and tracking. They are also able to provide bandwidth for mobile terminals with omnidirectional antennas. The features of the MEO satellite include a higher transmission power and unique antennas that allow for a smaller footprint.

HIGHLY ELLIPTICAL ORBIT (HEO)

A satellite operating in the Highly Elliptical Orbit (HEO) has a maximum altitude comparable to that of a satellite in the geosynchronous orbit (GEO) and a minimum altitude comparable to that of a satellite in the low earth orbit (LEO).[13]

In order to ensure continuous coverage, two satellites in the HEO layer can be used and their timing can be controlled so that one always remains visible for a longer period. This is due to the nature of how the satellites operate in the highly elliptical orbit.

The satellite would move much faster when it is closer to the earth due to the gravitational pull than it is when farther away. Doing so can allow it to provide coverage over any point of the Earth.

Satellites in the highly elliptical orbit can cover high latitude and polar regions and are not constrained to equatorial orbits as compared to satellites in the GEO layer. The highly elliptical orbit also offers users a more ideal orbit for scientific observation, monitoring, analysis, and forecasting.

13 Center for Strategic and International Studies (2022) Popular Orbits 101, retrieved from https://aerospace.csis.org/aerospace101/earth-orbit-101/

CONNECTIVITY APPLICATIONS

The recent developments in communication technology have given customers a wider range of options allowing them to choose the solution that best fits their connectivity requirements. These options can range from terrestrial communication systems to satellite communication systems with each option offering its own unique set of advantages and disadvantages for organisations and their various operations.[14]

Due to their broad coverage and ease of implementation, the use of satellite networks and other associated technologies now benefit a wide range of applications. However, the value of terrestrial communication options remains and can be used to complement satellite networks. Here we summarise the main categories of communication systems and demonstrate how they enable digital transformation in shipping.

Due to their broad coverage and ease of implementation, the use of satellite networks and other associated technologies now benefit a wide range of applications.

14 ACS College of Engineering (2020) Satellite Applications, retrieved from https://www.acsce.edu.in/acsce/wp-content/uploads/2020/03/Satellite-Applications-Module-5.pdf

FIXED SATELLITE COMMUNICATION

These are satellite services designed for commercial communication purposes wherein ground equipment is set at certain locations to receive and transmit signals. Most of the world's domestic and international services are supported by fixed satellite services. Several well-known fixed satellite communications services include fixed Very Small Aperture Terminal systems, or VSAT.

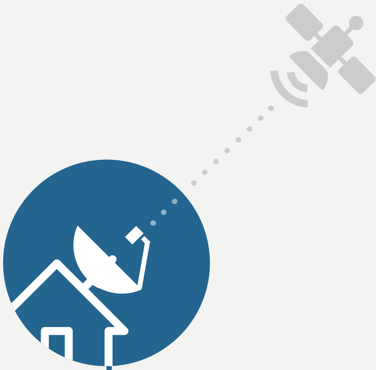
VSAT can consist of a two-way ground mounted antenna configured to point to its corresponding satellite or a stabilised maritime VSAT antenna with a tracking dish that has sizes vary from 0.75 to 3.8 metres. A network operating via VSAT is a form of data transmission technology that is utilised for high-frequency transmission needs and many different types of data management. As VSAT bounces the signal from satellites instead of transmitting through physical means like an ethernet connection, it can be utilised in place of a sizable physical network. This system can be deployed with multiple small terminals in dispersed locations and connected to a central hub via the satellite. VSAT satellite technology is also available in a variety of frequencies, forms, and sizes. The working frequencies are often C-band and Ku-band, and they function with various networks, such as Star Networks, with a private hub and Point-to-Point Networks with customised private hubs.

MOBILE SATELLITE COMMUNICATION

Mobile satellite communication systems are satellite services that utilise a wide range of portable receivers and transmission equipment to provide communication for users based on various sea, land, and air environments. This system requires mobile stations to operate. From these stations, mobile signals are transmitted to the receiving Earth-based radio stations through the aid of an artificial satellite.

These systems are frequently used in both onshore and offshore applications for their operational flexibility. They are also identified as effective measures in disaster prevention strategies and have been valuable for the needs of users operating in remote environments. For organisations in the maritime and aeronautical industries, mobile satellite systems are a critical part of their communication networks and data management processes.

In the maritime industry, mobile VSAT systems are also available and are designed to be self-stabilising so that it can track and maintain a precise connection to the artificial satellite. These systems are playing an increasingly significant role in enabling the development of digital applications onboard ships. These applications can range anywhere from voyage optimisation solutions to increased connectivity options for seafarers to contact their families. The emergence of these technologies is highlighting how the functional capabilities of satellites will continue to serve the industry as a foundational component in its digital transformation.



BROADCAST SATELLITE COMMUNICATION

Broadcast satellite services are designed for direct consumer applications, primarily for the broadcasting of radio and television shows. This service allows for the transmission of broadcast signals over or through a satellite network.

These broadcast signals typically come from a television or radio station and are then uploaded using a satellite to an artificial satellite operating in the geostationary orbit. Once the signals are received at this point, they are redistributed or retransmitted to their predetermined reception locations through an open or secure channel. Base stations such as small home satellites or those owned by local cable networks or media distribution companies are then able to receive these signals to deliver to their users.

These broadcast satellite services also offer a higher transmission power output, use smaller ground equipment, and require less antennas to pick up transmission signals. Common broadcast satellite services include digital programming, digital audio services, and increasingly, high-definition television. Currently, broadcast satellite communication services continue to benefit users as global video and audio channels are increasing and are now becoming easily accessible for both cable and broadcast networks.

TERRESTRIAL COMMUNICATION

Terrestrial communication systems are commonly designed for the transmission of signals using Line-Of-Sight (LOS) communication. This requires the signal to travel to the receiving antenna in a straight and unobstructed path.

In this approach, transmitted signals are converted from baseband signals to microwave signals, and received signals are converted from microwave signals to baseband signals. These signals are relayed from one station to another. In situations wherein extending the range is required, multi-section relays or repeaters are used to amplify and retransmit signals to the destination station.

Terrestrial communication systems are commonly designed for the transmission of signals using Line-Of-Sight.

* For detailed technical overview, **see Satellite Technology Supplement starting on page 38.**

HOW CONNECTIVITY GENERATES VALUE AND NEW OPPORTUNITIES

A GUIDE TO DEVELOPING A CONNECTIVITY STRATEGY

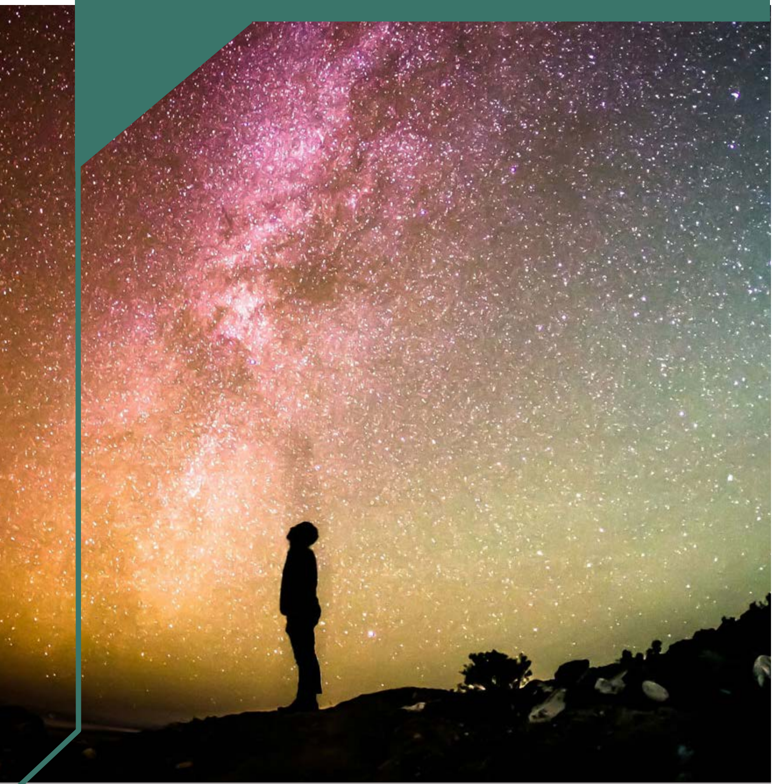
The end goal of any business is to be profitable and financially sustainable. Financial health isn't the only thing that stakeholders need to build in. Increasingly, organisations are aiming to achieve the 'triple bottom line' of increased profits, community support, and environmental protection. By harnessing data and digital tools, organisations can make better decisions, develop better products, and deliver better services.

> *"From a business perspective, the challenge that connectivity overcomes is one of enterprise risk management. For most modern vessels and the maritime sector in general it is difficult to continuously update IT equipment. Left unmanaged, these things pose real risks to large businesses. It is the reduction of those risks that ensures that we continue to invest in improvements in these areas."*
>
> **Chris Sepp, VP IT at Atlas Corp. (Seaspan)**

A good connectivity strategy addresses the flow of data and information according to desired use cases and outcomes. It intends to provide organisations with a detailed plan that considers internal factors, such as business goals and organisational readiness, and external factors, such as the availability of resources and the intended timeline. The connectivity strategy can act as a roadmap to where the business wants to go and will ultimately guide decision making in achieving their financial, regulatory, and organisational growth targets by showing what is possible at each stage.

Working from an "as-is" position, a good strategy aims to bring the company closer to the "to-be" state. This may sound straightforward, but it's more complex. This is because, sometimes, there are strategies that depend on one another or overlap. The process of finding the right enabling technology and infrastructure may be a little daunting, but when treated as a step-by-step process allows everything to be more manageable.

Working from an "as-is" position, a good strategy aims to bring the company closer to the "to-be" state.



The framework essentially operates as a decision tree, guiding the organisation towards selecting and developing a connectivity strategy that fits best with their mission objectives and limitations.

DEVELOPING THE CONNECTIVITY STRATEGY

This example framework is designed to guide business executives and managers in the process of developing their connectivity strategy. It takes into account three components in order to provide organisations with an option that will allow them to achieve their strategic objectives. These components are the organisation's business goals, the technologies that will enable them to achieve these goals, and the influencing factors that will determine the best potential technology options to support them in the entire process.

The framework essentially operates as a decision tree, guiding the organisation towards selecting and developing a connectivity strategy that fits best with their mission objectives and limitations.

BUSINESS CONNECTIVITY STRATEGY FRAMEWORK

OUTCOMES

COMMERCIAL

1. Improve market position
2. Improve fleet utilisation
3. Streamline commercial processes

TECHNICAL

1. Reduce overall emission output
2. Develop operational preparedness to new industry requirements
3. Enable operational transparency

CREW

1. Improve crew retention
2. Improve staff competence
3. Improve crew health & wellness

FUNCTIONS

- Fleet / Asset Tracking
- Process Automation
- Digital Twins
- Internet of Things
- Cloud Platforms
- Augmented & Virtual Reality

DATA & ANALYTICS

PRACTICALITIES

RESOURCE AVAILABILITY	INVESTMENT REQUIREMENTS	ORGANISATIONAL READINESS	TIMELINE

FOCUS

SHIP TO SHORE

Focus on a communication technology option that primarily serves ship to shore communication to enable impactful commercial targets.

Invest in high bandwidth options with robust security features.

DIGITAL INTEGRATION

Focus on a communication technology option that primarily serves to enable digital integration onboard ships to modernise technical operations.

Invest in secure, low latency networks that offer flexible data usage terms.

CREW WELFARE

Focus on a communication technology option that primarily serves to enhance crew welfare and connectivity.

Invest in secure and reliable networks that provide fast Internet speeds and consistent service.

DATA TRANSFER

Focus on a communication technology option that primarily focuses on critical data transfer operations.

Invest in reliable and high bandwidth options that have robust security features and provide consistent data transfer rates.

According to a study featured in the Harvard Business Review, high-growth organisations are inclined to base their strategy on a specific purpose.

WHAT ARE THE BUILDING BLOCKS OF A BASIC CONNECTIVITY STRATEGY?

It is important that an organisation understands their purpose in each category. A guiding principle that propels their strategy towards an ideal future state. This framework starts the planning and development process by identifying well-defined business goals, followed by gaining an understanding of what technological enablers will be used, and what their organisation's capabilities and limitations are. Each component is presented below and is designed to generate a collaborative discussion within organisations to effectively manage expectations.

BUSINESS GOALS

According to a study featured in the Harvard Business Review, high-growth organisations are inclined to base their strategy on a specific purpose.[15] This approach is supported by the idea that sharing the same values and beliefs act as the motivating factor for the entire organisation to buy into a strategic direction.

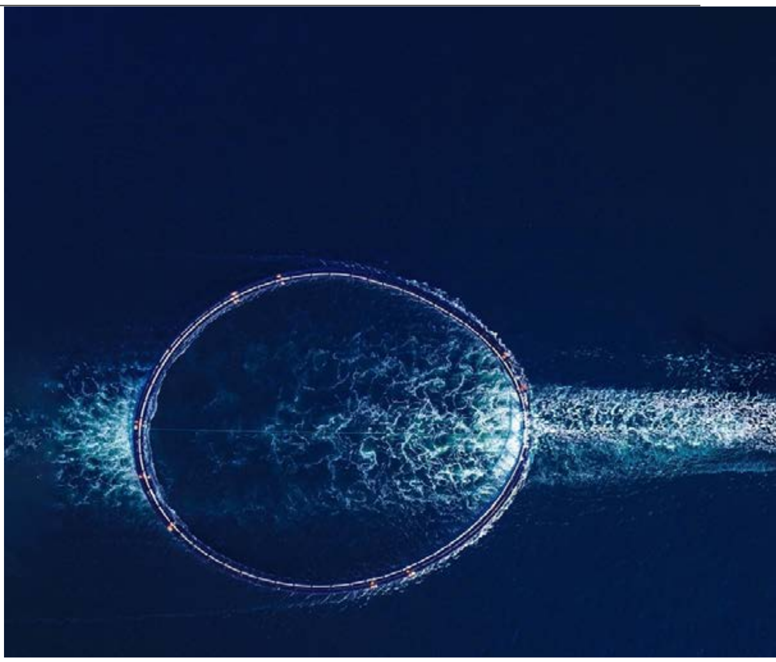
In our example, business goals are also segmented according to their management focus within a maritime organisation, namely the commercial, technical, and crew-related aspects. Identifying the business goal primarily answers the question - what do we want our connectivity strategy to effectively address?

15 T. W. Malnight, I. Buche, and C. Dhanaraj (2019) Put Purpose at the Core of Your Strategy; Harvard Business Review; extracted from https://hbr.org/2019/09/put-purpose-at-the-core-of-your-strategy

From a commercial perspective, business goals might include:

- **Improving market position:** This goal focuses on how an organisation can competitively position its products and/or services to ensure that customers choose them over competing offers. This goal can be achieved through marketing initiatives, pricing control, and quality management, but will ultimately make use of data-driven and evidence-led processes.
- **Improving fleet utilisation:** This goal focuses on improving the resource efficiency of each ship within an organisation's fleet. This involves actively monitoring each vessel's status and being aware of the commercial opportunities available.
- **Streamlining commercial processes:** This goal focuses on the resource efficiency of an organisation's entire commercial process. This involves reducing costs and identifying avenues for automation and optimisation.

Business goals are also segmented according to their management focus within a maritime organisation, namely the commercial, technical, and crew-related aspects.



From a technical perspective, business goals might include:

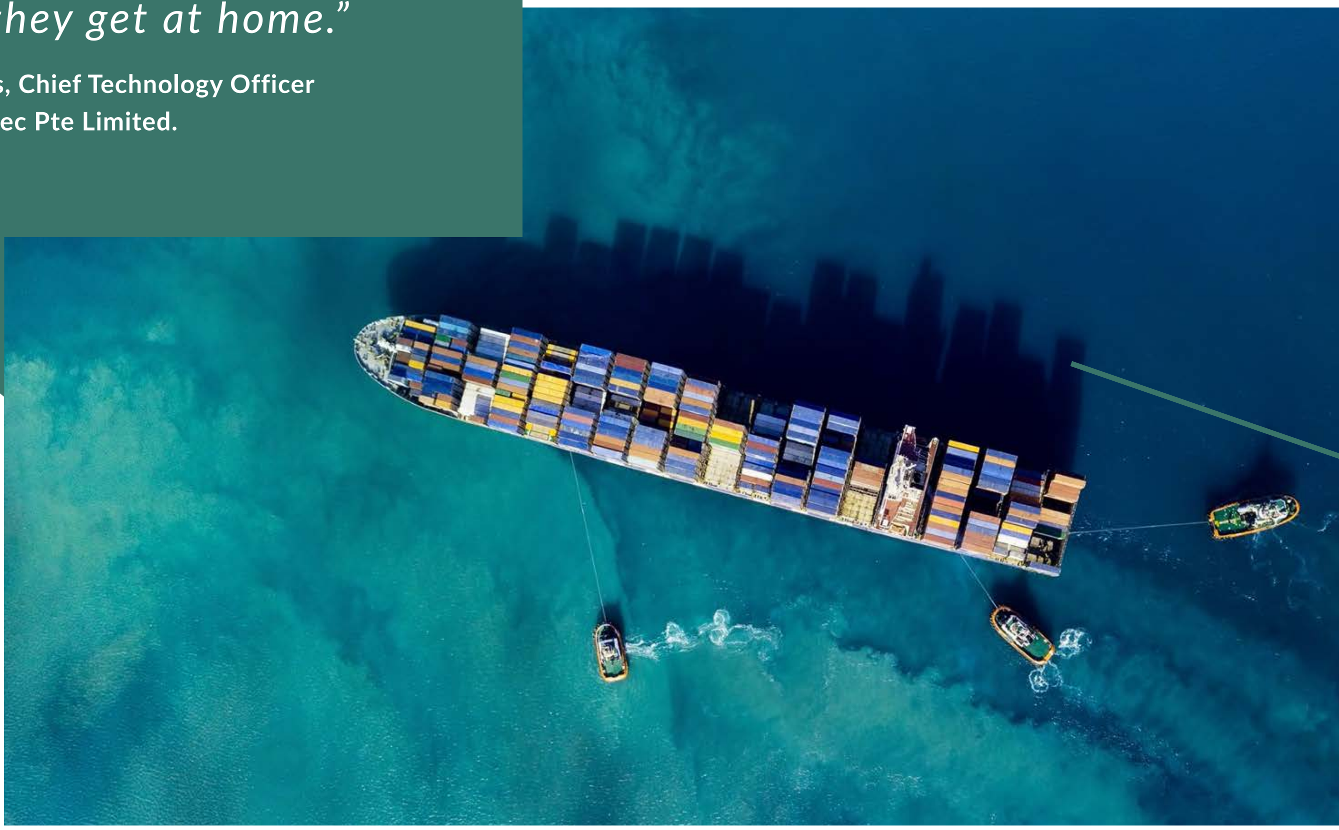
- **Reducing overall emissions:** This involves the reduction, management, monitoring, and reporting of emission outputs in accordance with internal processes and industry regulations.
- **Developing operational preparedness to new industry requirements:** This goal aims to help an organisation become more agile in adjusting to new fuel types, and new compliance and regulatory requirements, such as cyber security, data usage, and digital integration. This goal covers a wide range of technical concerns which may involve fleet renewal initiatives and/or considerable infrastructure projects.
- **Enabling operational transparency between ship- and shore-based teams:** This goal aims to achieve transparency between ship and shore-based teams on concerns such as bunkering, spares provision, and maintenance operations. This would also include the collection, processing, and management of information that supports critical technical functions and activities.

"The problem is that crews are getting harder to find and they can go anywhere. If you want to attract and keep a good crew, you have to do something over and above good wages. We recognised very early on that high quality internet onboard our ships was going to be important to attracting and retaining quality crew. We are always looking at what it is that our crews want and how we can make their lives better. The ultimate goal is to provide them with the same level of connectivity that they get at home."

Neil Giles, Chief Technology Officer at Petredec Pte Limited.

From the crew-related perspective, business goals might include:

- **Improving crew retention:** This goal is aimed at improving crew-related organisational processes. This involves processes such as crew changes and onboard work protocols.
- **Improving staff competency:** This goal focuses on the education and training of both ship and shore-based staff on various disciplines such as maritime operations, business operations, and the usage of emerging technologies such as data analytics, and artificial intelligence.
- **Improving crew health and wellness:** This goal is aimed at improving the condition of seafarers onboard ships. This involves the improvement of processes surrounding seafarer safety and well-being, covering areas such as physical health, mental health, and working conditions.



ENABLING TECHNOLOGIES

Organisations shouldn't expect the right outcomes without first finding the right tools. But how are those tools identified at the planning stage?

The enabling technologies included in this framework present multiple use cases and capabilities, all of which are supported by data as the foundational component. At the base of any good connectivity strategy is the requirement to collect and analyse data. It is the DNA of transformational change, and this is why data can be linked to every business goal and considered a prerequisite of a mature connectivity strategy.

For commercial goals, enabling technologies might include:

- Fleet / Vessel Tracking
- Process Automation

For technical goals, enabling technologies might include:

- Digital Twins
- Internet of Things

For crew-related goals, enabling technologies might include:

- Cloud Platforms
- Augmented/Virtual Reality

At the base of any good connectivity strategy is the requirement to collect and analyse data.

INFLUENCING FACTORS

The following factors will play a role in how organisations can assess where they are currently at and where they could end up.

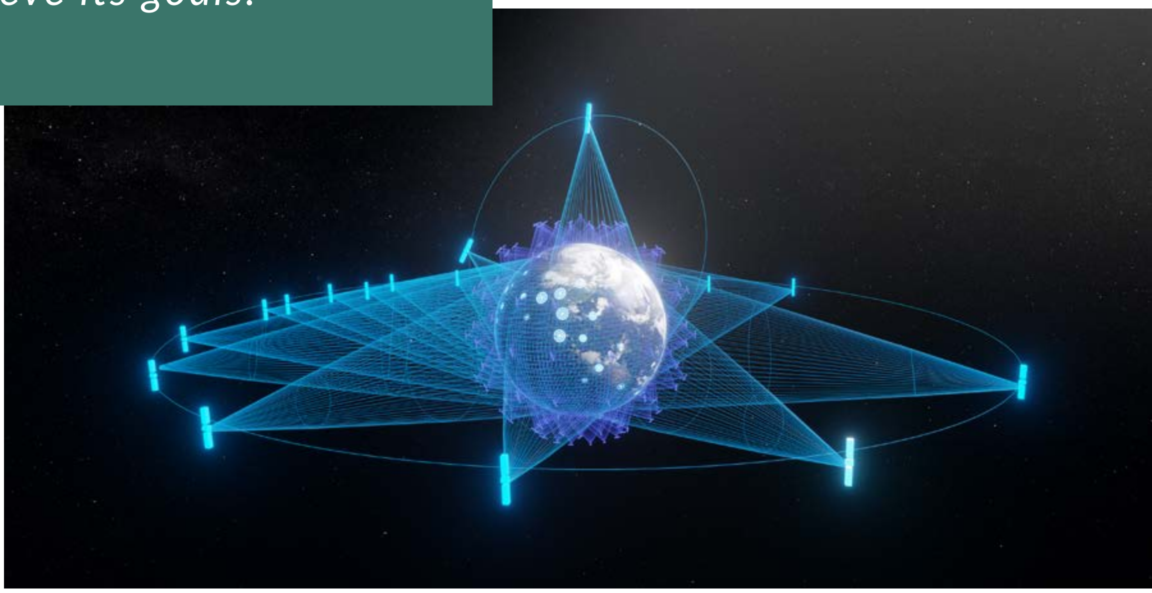
- **Resource Availability** refers to the status of the required technological infrastructure and the supporting resources being obtainable and accessible for the organisation.
- **Investment Requirements** refers to the organisation's capability and willingness to invest in the assets and resources required for the successful implementation of the connectivity strategy.
- **Organisational Readiness** refers to the organisation's level of maturity to engage and execute the connectivity strategy.
- **Timeline** refers to the intended duration of the strategy's implementation.

COMMUNICATION TECHNOLOGY OPTIONS

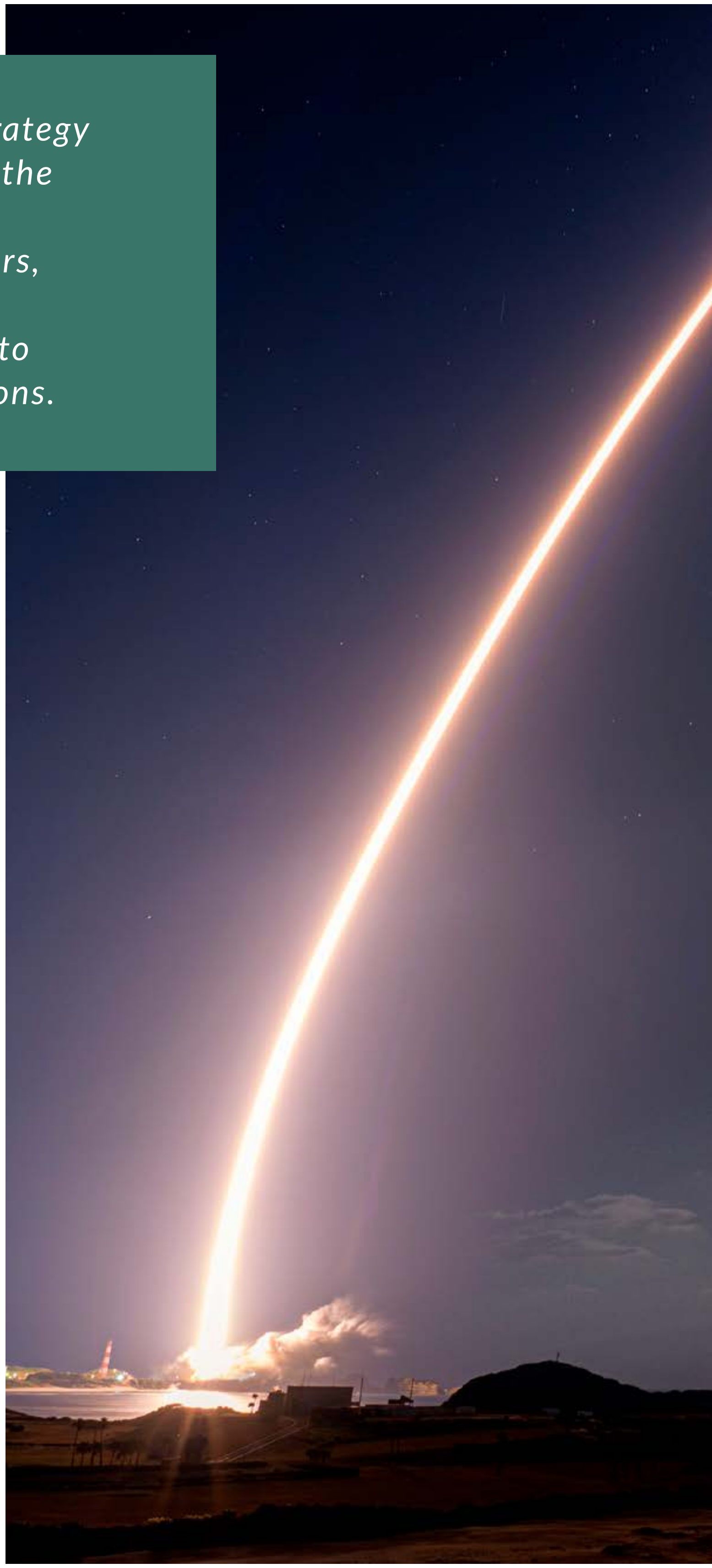
As we have seen, a good connectivity strategy addresses the kinds of technology that will be used by the organisation to achieve its goals. In this framework, technology options are characterised by the following:[16]

- **Bandwidth** - referring to the theoretical measure of the amount of data that can be transferred over a network for a definite period. It is a commonly used metric for network performance and refers to the network's capacity to transmit data.
- **Latency** - referring to the amount of time it takes for data to travel from one point on a network to another. Faster and more responsive networks are said to have low latency.
- **Network Reliability** - referring to the availability of an operating network and the capability of the satellite to transmit data over certain geographic areas. Uptime means a network is up and running, while downtime refers to the time when a network is unavailable. This is especially important for ships trading on global routes.
- **Security** - referring to the encryption equipment used in the satellite system. This refers to the coding and decoding process done during the transmission.
- **Service uniformity** - referring to the quality of the transmission signal being consistent. A poor service uniformity would result in a fluctuating transmission signal and an excellent service uniformity would result in a consistent transmission signal.
- **Service Level Agreement (SLA)** - SLA's ensure that the customer receives the guaranteed service and support needed after the delivery phase, including the contracted Committed Information Rate (CIR).

A good connectivity strategy addresses the kinds of technology that will be used by the organisation to achieve its goals.



16 A. Hawkes, ConsoleConnect.com (2021) Understanding Network Speed And Latency, extracted from https://blog.consoleconnect.com/understanding-network-speed-and-latency#:~:text=throughput%3A%20While%20bandwidth%20tells%20you,its%20destination%20across%20the%20network.



It is important to remember that a strategy is an iterative process which requires the organisation to gather feedback from both internal and external stakeholders, collect more data, analyse the key performance indicators, and be open to adjusting to potential strategic revisions.

STRATEGY IMPLEMENTATION

Implementing a connectivity strategy is a continuous process of communicating the business goal, monitoring the performance of the enabling technologies, managing current resources, preparing for future requirements, and reassessing the progress of the strategy and how it is impacting the organisation and its goals.

It is important to remember that a strategy is an iterative process which requires the organisation to gather feedback from both internal and external stakeholders, collect more data, analyse the key performance indicators, and be open to adjusting to potential strategic revisions. Creating a measurable standard for the strategy's output makes it easier for the organisation to review the implementation process and to potentially gain additional information about their organisation that could have only been gained through a retrospective review.

STAYING AHEAD OF THE GAME

PUT CYBER SECURITY AT THE CENTRE

Cybersecurity is an ever-present risk and choosing the right connectivity provider can be pivotal to its successful management. Consider the segregation of networks according to dedicated user segments: Commercial/IT for Business, Technical/OT and Crew/IT for Crew. Cyber security hygiene is vital. Put in place hard limits in terms of connectivity access - humans are often the weakest link in terms of cyber security.

Consider installing:

- Physical barriers (restricted peripheral device access)
- Digital access barriers (restricted software installations and website access)
- Scheduled security checks on all administrative access accounts

Build independent (and ideally automated) operations monitoring function to assess malicious cyber behaviour from multiple users

Focus on the data model being the foundational component of developing a database.

BUILD A DATA MANAGEMENT SYSTEM

Data Management underpins all forms of digitalisation in shipping. Build a management regime that considers the following:

- In data collection and reporting applications, data quality should be controlled at the source
- Focus on the data model being the foundational component of developing a database. This will affect how an organisation will be able to use and scale their data.
- Ensure consistent data exchange standards - formats, capabilities, and limitations in sharing data through different platform providers

Build a strategy that allows for continuous and proactive monitoring of digital activities aboard ship.

THE CREW NETWORK

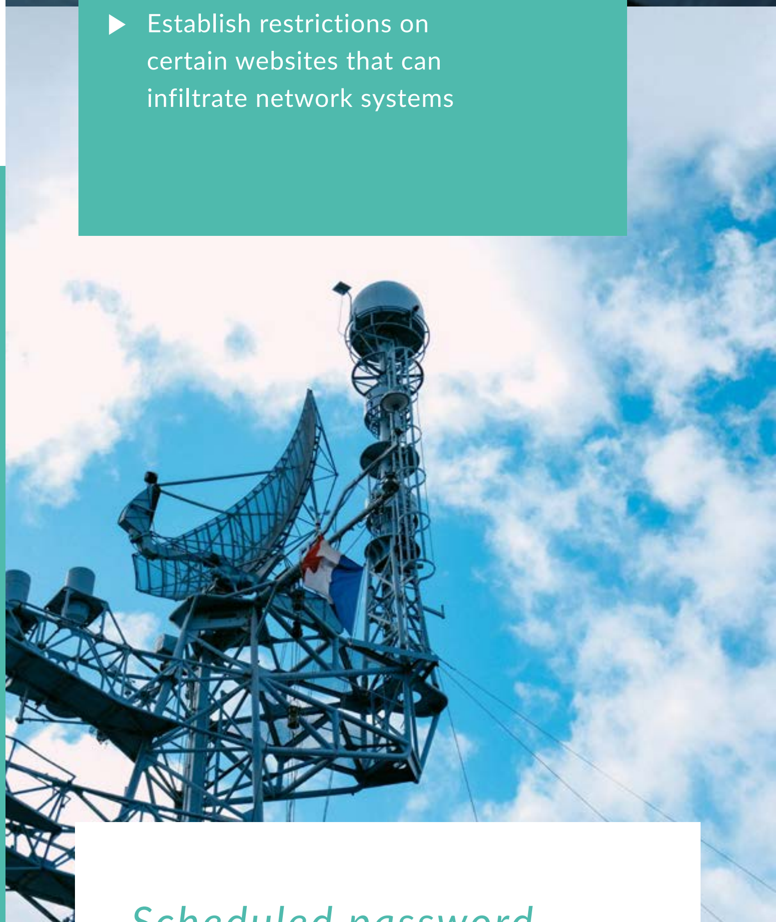
Establish a responsible Internet usage policy and proper cyber security hygiene

- Scheduled password changes, consistent cyber security training and drills onboard
- Establish restrictions on certain websites that can infiltrate network systems

THE BUSINESS NETWORKS

Consider creating a dedicated network for critical and non-critical commercial uses:

- Critical use case - i.e. financial and regulatory reporting applications
- Non-critical use case - i.e. daily condition reporting
- Build a strategy that allows for continuous and proactive monitoring of digital activities aboard ship:
- Reviewing all forms of software being used and ensuring high levels of cyber security hygiene by changing passwords at set intervals and controlling user permissions - prior to installation, updating, and uninstallation
- Establishing a dedicated and independent team to monitor potential illicit digital activities
- Create a dedicated and secure interface for client-related data (including multiple user redundancies - confirmations, restricted access, reported movement)



Scheduled password changes, consistent cyber security training and drills onboard

OPERATIONAL TECHNOLOGY (OT) NETWORKS AND EMERGING CAPABILITY

CREATE SECURE AND SEGMENTED NETWORKS with physical access redundancies and boundary protection measures - separate and secure network for remote engine control and remote navigation control with their own user access requirements

ESTABLISH SECURE ONE-TO-ONE DATA CONNECTIONS with end points requiring strict user access controls such as log-in redundancies and monitored access.

CARRY OUT CONTINUOUS AND PROACTIVE MONITORING OF DIGITAL ACTIVITIES:

- Reviewing all forms of software being used and ensuring high levels of cyber security hygiene by changing passwords at set intervals and controlling user permissions - prior to installation, updating, and uninstallation
- Establish a dedicated and independent team to monitor potential illicit digital activities

CREATING A DEDICATED AND SECURE INTERFACE FOR OPERATIONAL DATA
data related to cargo, navigational plans, ship conditions, etc (Approach will include multiple user redundancies - confirmations, restricted access, reported movement)

Create secure and segmented networks with physical access redundancies and boundary protection measures.

CONCLUSION

When considering the network effect of digital tools on ship operations, taking a strategic approach to connectivity is crucial to generating maximum impact.

As this report examines, many technologies are required to work together to deliver impacts that affect change in shipping. New capabilities in voyage and port call optimisation, trade facilitation, automation, and condition–based maintenance to name just a few, are minimally impactful on their own.

Connectivity is the lifeblood of digitalisation in the maritime industry. It provides the pipelines and highways along which data can flow; integrating ships into global systems of connected trade and commerce.

But when orchestrated and combined within an interconnected system, digital technologies can give rise to significant gains in efficiency, customer value, and profitability.

Connectivity is the lifeblood of digitalisation in the maritime industry. It provides the pipelines and highways along which data can flow; integrating ships into global systems of connected trade and commerce. Choosing the right connectivity network and implementation partner is pivotal to the current and future success of a digitalisation and decarbonisation strategy and to the achievement of an operator's business goals more generally.

At the base of any good connectivity strategy is the requirement to collect and analyse data. It is the DNA of transformational change and this is why data can be linked to every business goal and considered the prerequisite of a mature connectivity strategy. A good attempt at building a strategy takes into account three components: the organisation's business goals, the technologies that will enable them to achieve these goals, and the influencing factors that will determine the best potential technology options to support them in the entire process.

While this report provides a basic framework for building a connectivity strategy, piecing the many factors together requires a good understanding of the options available. As new satellite providers enter the market, it is vital to look at options holistically – it is not just the bandwidth and latency that counts. Reliability, cyber security, supplier partnerships, and expertise also play key roles. When considering the network effect of digital tools on ship operations, taking a strategic approach to connectivity is crucial to generating maximum impact.

SATELLITE TECHNOLOGY SUPPLEMENT

CONTENTS

OVERVIEW OF SATELLITE FREQUENCIES

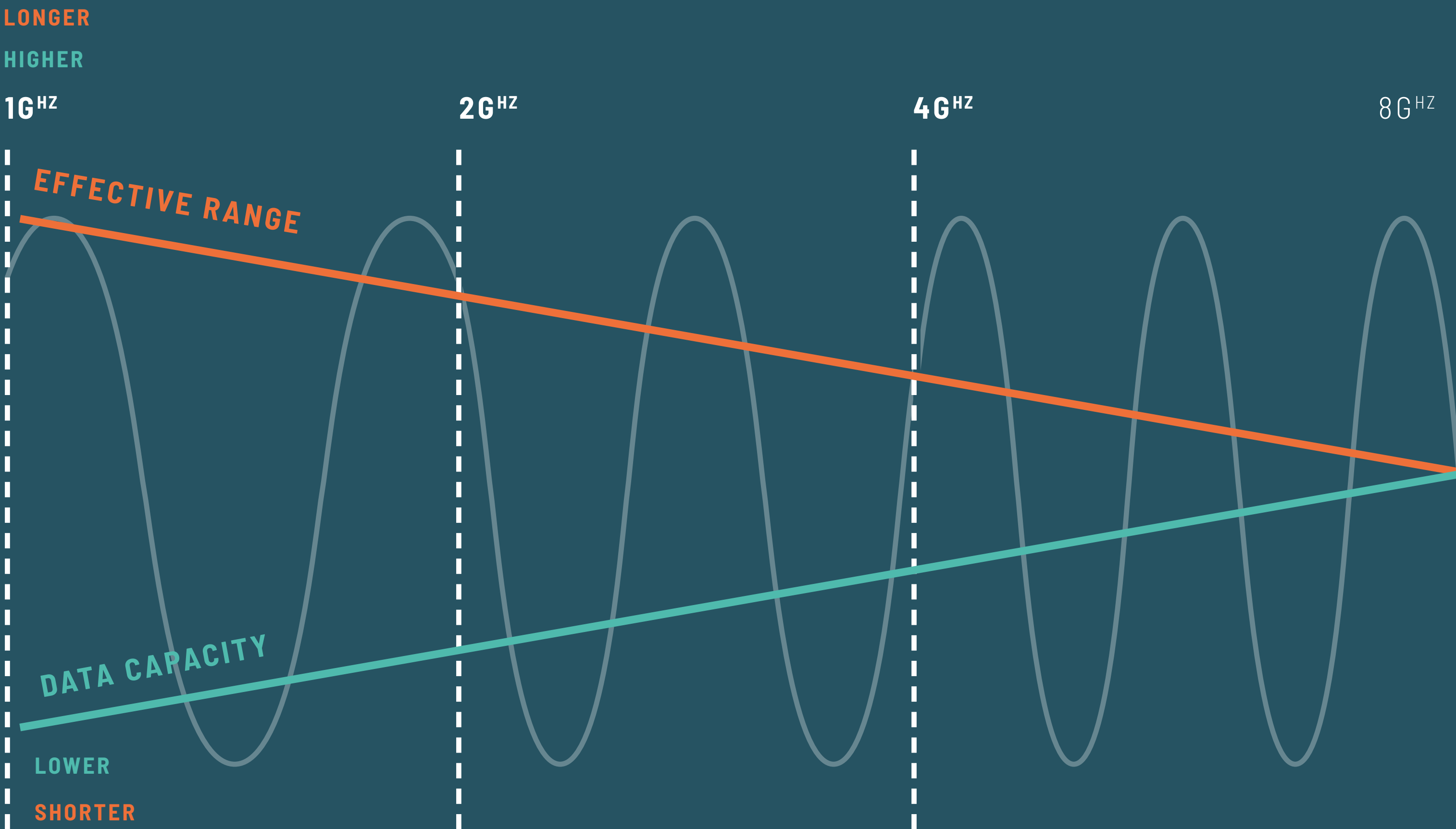
There are different satellite frequency bands that could be used with each having specific strengths and weaknesses. Wider bandwidths are often available in the higher frequency bands, but they are also more prone to signal degradation which is due to the absorption of radio signals from various atmospheric factors such as rain, snow, or ice. Congestion has also become a significant problem in the lower frequency bands as a result of the growing utilisation, number, and size of satellites. Ongoing developments are allowing companies to use higher frequency bands in more resource-efficient ways. This section highlights these frequency bands and how they are being used by different organisations.[17]

17 European Space Agency (2022) Satellite Frequency Bands, accessed from https://www.esa.int/Applications/Telecommunications_Integrated_Applications/Satellite_frequency_bands#:~:text=Ku%2Dband%20(12%E2%80%9318%20GHz)&text=In%20Europe%2C%20Ku%2Dband%20downlink,satellite%20services%2C%20such%20as%20Astra.

TABLE 1. FREQUENCY BAND CHARACTERISTICS

FREQUENCY BAND	FREQUENCY RANGE	APPLICATIONS	STRENGTHS & WEAKNESSES
L-Band	1 GHz to 2 GHz	GPS devices, maritime navigation signals	▶ **S:** Less rain fade, supports smaller antenna sizes, cheaper ▶ **W:** Frequency Spectrum is scarce
S-Band	2 GHz to 4 GHz	Radar and satellite communications, common in maritime and aeronautical industries	▶ **S:** Less rain fade ▶ **W:** Narrow frequency spectrum, larger antenna sizes
C-Band	4 GHz to 8 GHz	Satellite communication and television networks	▶ **S:** Less signal attenuation (reduction in strength), wider coverage ▶ **W:** Relatively lesser throughput, larger antenna sizes
X-Band	8 GHz to 12 GHz	Common in military applications such as weather monitoring, vessel traffic control, asset tracking	▶ **S:** Less rain fade, supports smaller antenna sizes ▶ **W:** Supports a limited number of clear air measurements for radar applications
Ku-Band	12 GHz to 18 GHz	Satellite communications and direct broadcast services	▶ **S:** Higher throughput, supports smaller antenna sizes ▶ **W:** Prone to rain fade/signal degradation - not ideal in areas experiencing a lot of rainfall
Ka-Band	26 GHz to 40 GHz	High speed data communication, high resolution and close-range radars, critical data transmission operations	▶ **S:** Higher throughput, high power transmission, supports smaller antenna sizes ▶ **W:** Prone to rain fade/ signal degradation

OVERVIEW OF SATELLITE FREQUENCY BANDS



L-BAND

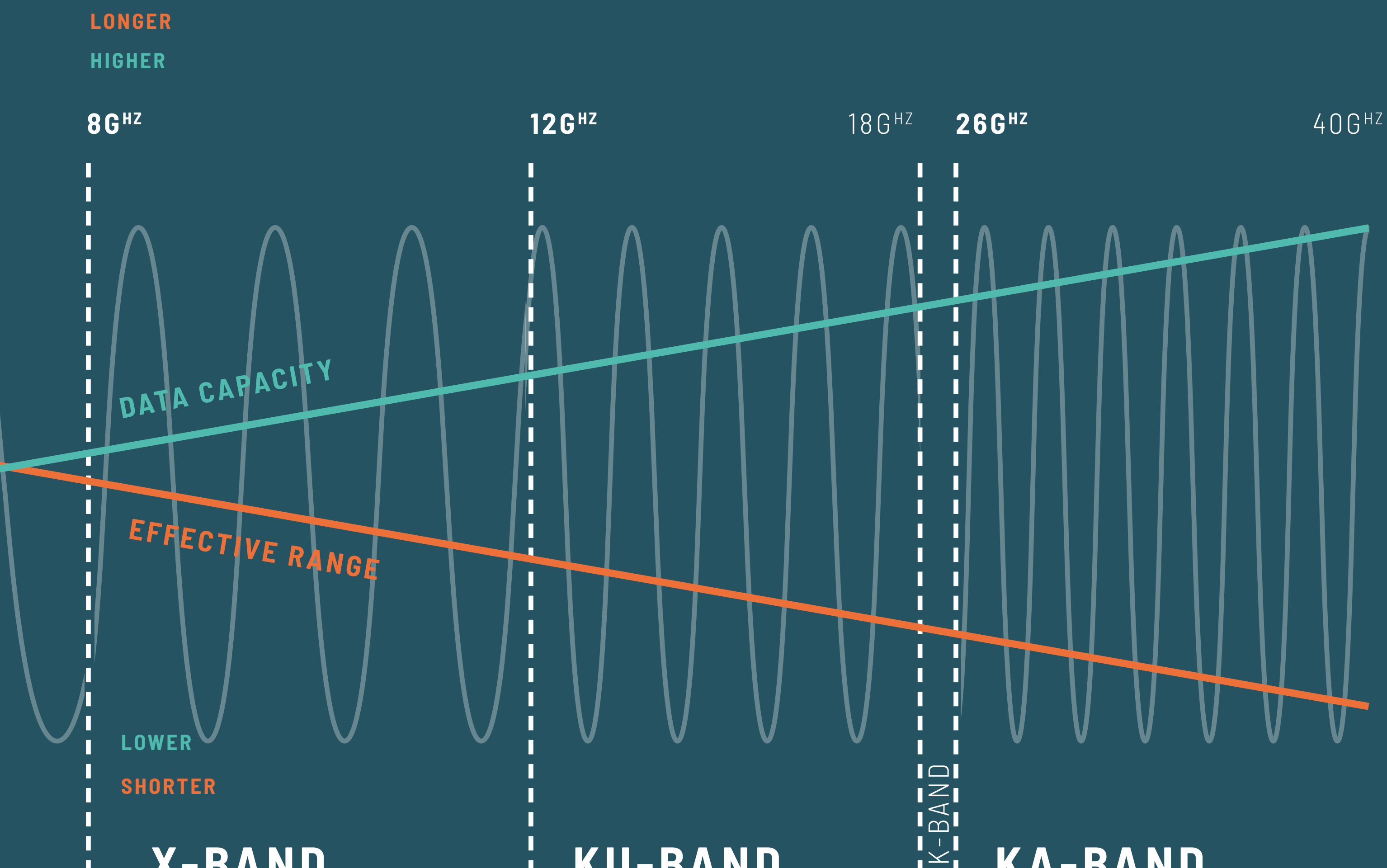
Frequencies in the L-band range from 1 GHz to 2 GHz. Several applications include Global Positioning System carriers, satellite mobile phones that offer communications on land, sea, and in the air, and satellite radio. This frequency is also one of the primary operating ranges for radar technology, satellite navigation, telecommunications, and aerial surveillance.

S-BAND

The operating range of S-band frequencies is from 2 GHz to 4 GHz. This frequency band is commonly used for radar and satellite communication applications. The S-band also acts as an efficient transmission channel for critical real-time data and for environments prone to signal degradation thanks to its high signal resilience. This is why the S-band is widely used in the maritime and aeronautical industries.

C-BAND

C-band frequencies range between 4 Ghz to 8 GHz. They are mostly employed for satellite communications, satellite television networks, or unprocessed satellite feeds. Since they are less prone to signal deterioration than the Ku-band, they are also often used in specific areas of the world where heavy rain or other intense weather conditions are more common.



X-BAND

Frequencies in the X-band range from 8 GHz to 12 GHz. The X-band is commonly used for modern radar technologies and can be seen in many applications such as weather monitoring, vessel traffic control, and asset tracking. This frequency also allows for more efficient data transmissions with less occurrences of interference and less signal degradation. This leads to higher throughputs from small terminals and considerable savings in terms of bandwidth as compared to Ku and Ka bands.

KU-BAND

The range of Ku-band frequencies spans from 12 GHz to 18 GHz. Their applications are commonly in satellite communications and direct broadcast services. The Ku-band experiences less terrestrial interference and often allows for a higher satellite transmission output availability. However, this frequency band is more prone to signal degradation especially from heavy rains.

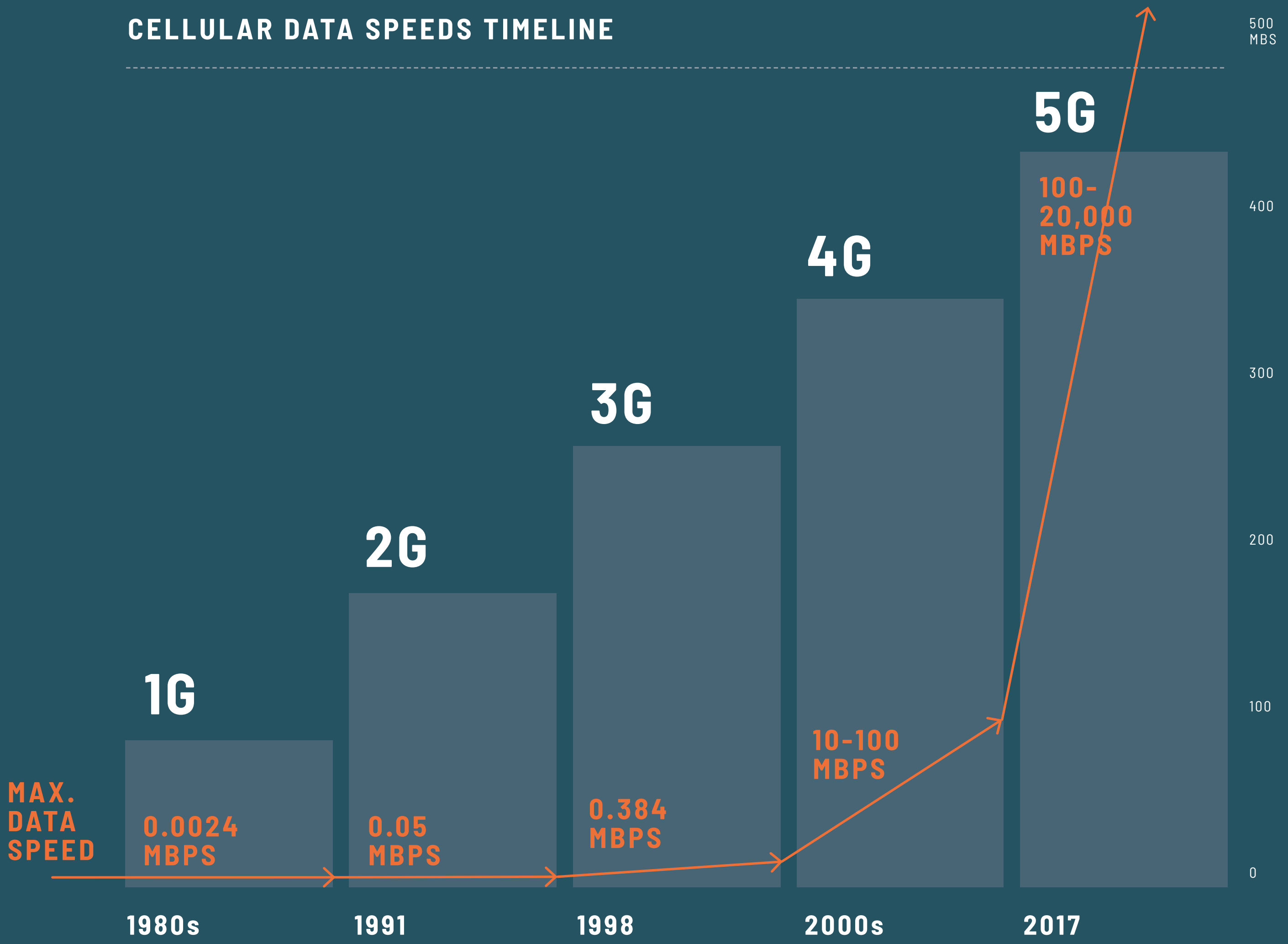
KA-BAND

The range of Ka-band frequencies is from 26 GHz to 40 GHz. This frequency band is commonly applied for high-speed data communication satellites, high-resolution and close-range radars, and critical data transmission operations. It is also capable of having smaller dish antennas which allow for cheaper and easier installation. However, the Ka-band is significantly prone to signal degradation from heavy rains and harsh weather.

OVERVIEW OF CELLULAR NETWORK TECHNOLOGY

In order to support the increasing data transfer requirements of commercial and industrial activities for both communication and entertainment purposes, cellular networking has gained wide acceptance beyond the personal computing space and has become a critical factor for many organisations and industries.[18] The following overview demonstrates how cellular networking technology has progressed over the years.

CELLULAR DATA SPEEDS TIMELINE



18 Data Alliance (2022) Cellular Wireless Technologies, accessed from https://www.data-alliance.net/blog/cellular-wireless-technologies-5g-lte-4g-gsm-3g-2g-and-6g/

CURRENT NETWORK TECHNOLOGY

3G

3G mobile technology was launched in 1998. Its features included video calling and mobile internet. The maximum transmission speeds are at 2 Mbps when stationary, and 384 Kbps when moving. It also offered faster data transfer rates and better audio quality for users compared to its predecessors. The adoption of the technology saw countries investing heavily into frequency licences and new communication networks. It was also at this time that the rapid expansion of the mobile phone market accelerated the growth of the technology.

4G

4G or the Fourth Generation was developed in the 2000s. It allowed for high-definition mobile TV, video conferencing and many more. It also offered maximum transmission speeds of around 10 Mbps when moving and around 100 Mbps when stationary. 4G technology relies on an Internet Protocol-based communication system and also uses multiple transmission and receiving antennas to provide mobile devices with a very high level of bandwidth efficiency.[19]

5G

The Fifth Generation of mbvvobile cellular technology or 5G was developed around 2017. It offers similar features to 4G but with higher peak capacity, less latency, and larger bandwidth size. Like previous versions of the technology, 5G operates as a cellular network but becomes more robust as it allows users to connect their devices to various small cells as base stations instead of the need for cell towers as compared to 4G networks.[20]

19 EE Times (2005) Wireless: Carriers look to IP for backhaul, accessed from https://web.archive.org/web/20110809025050/http://www.eetimes.com/electronics-news/4052152/WIRELESS-Carriers-look-to-IP-for-back-haul

20 TechTarget (2022) 5G vs 4G: Learn the Key Differences between them, accessed from https://www.techtarget.com/searchnetworking/feature/A-deep-dive-into-the-differences-between-4G-and-5G-networks

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