Australian Government
Geoscience Australia

Submission to the Inquiry into the availability and access to enabling communications infrastructure in Australia's external territories

Geoscience Australia

19 January 2021

Contents

Terms of Reference

This submission addresses the Terms of Reference (ToR) of the Joint Standing Committee on the National Capital and External Territories inquiry into the *Availability and access to enabling communications infrastructure in Australia's external territories*, including:

1. the availability of, and access to communications technologies and infrastructure in each of the external territories;
2. future opportunities in enabling communications technologies and infrastructure in each of the external territories including telecommunications services, submarine cables, satellite capabilities;
3. opportunities and barriers arising from current and potential future communications infrastructure in each of the external territories;
4. examining the economic benefits of improving the availability of, and access to communications infrastructure in each of the external territories; and
5. recommendations for any future communications technologies and infrastructure for each of the external territories.

Key Recommendations

In the context of providing precise positioning and rapid warning services, as well as advancing Australia's interests in Antarctica, Geoscience Australia (GA) recommends the Australian government:

1. Maintain existing communications infrastructure in the external territories to support hazard monitoring by GA's geophysical observatories; these are key nodes in a global observatory network and are essential for:
   - accurate navigation
   - monitoring natural and anthropogenic hazards in Australia and around the globe and providing real-time information on hazards to help safeguard Australian and neighbouring communities
   - underpinning Australia's international treaty obligations.
2. Maintain and enhance existing communications infrastructure in the external territories to ensure accurate and reliable positioning services to all Australians, and boost innovation and productivity across numerous industry sectors.
3. Enhance satellite communications technology on Australia's research vessels (RV *Investigator*, RSV *Nuyina*) to enable high reliability telepresence and data transfer when working offshore around the external territories. This will increase value for money, enhance scientific outcomes, and facilitate collection of high-quality information to support sustainable management of our marine assets and rapid growth of Australia's blue economy.
4. Improve communication links to Antarctica through high-bandwidth satellite communication to improve efficiency, enhance scientific outcomes, support best-practice environmental stewardship and Australia's interests in Antarctica.
5. Investigate the viability of an undersea fibre communications cable to Antarctica, including the following planning activities:
   - an engineering study to investigate the viability of establishing an undersea cable from Australia to Antarctica
   - detailed bathymetric surveys of the Antarctic continental shelf offshore Casey and Davis stations to identify potential cable routes
   - consultation with GA to access information regarding existing use and physical characteristics of the Australian marine jurisdiction

  - assessment of the value proposition of an undersea cable to Antarctica including exploring the option of an Antarctic space park to potentially lower the cost of the cable via a Public-Private Partnership.

  An undersea cable to Antarctica is the key to a full capability satellite ground station and would demonstrate Australian leadership and innovation in Antarctica.

6. If an undersea fibre communications cable is found to be viable:
   - develop an Antarctic satellite ground station to further support the polar orbiting Earth observation satellite missions, increase the availability of satellite data for environmental decision-making, boost growth of Australia's geospatial sector and potentially attract foreign investment.
   - develop a quasi-seismic array at the ends of the cable to improve earthquake and tsunami alert services and enhance community safety.

Introduction

Geoscience Australia (GA) is the national geoscience organisation that provides trusted information on Australia's geology and geography for government, industry and community decision making. GA's work covers the Australian landmass and marine jurisdiction, including external territories. GA delivers enduring data and advice that helps government, industry and the community to address challenges and enhance opportunities facing Australia now and into the future.

GA presents this submission for the inquiry into enabling communications infrastructure in Australia's external territories by the Joint Standing Committee on the National Capital and External Territories. This submission outlines the enabling communications technology used to support diverse geoscience and spatial activities conducted by GA, including geophysical and geodetic observatories and marine geoscience, in Australia's offshore islands and the Australian Antarctic Territory. These activities support Australian government priorities. This submission also identifies potential for new and improved communications capabilities, particularly in Antarctica, where GA has identified opportunities to enhance its science capabilities to support Australia's national interests.

Satellite Communications

Geophysical Observatories

Overview

GA's geophysical monitoring program (of which the external territory observatories are an essential component) is critical to ensure Australia's community safety by monitoring natural and anthropogenic hazards, including potentially tsunamigenic earthquakes and nuclear explosions. The impact of disasters on Australia's economy, environment and society can be significant and includes loss of life, loss of property and infrastructure, disruption to business, disruption to our livelihoods and damage our natural environment.

GA operates geophysical monitoring infrastructure in Antarctica (Davis, Mawson, Casey and Macquarie Island) and Australian offshore territories (Norfolk Island, Cocos (Keeling) Islands and Christmas Island). The geophysical monitoring infrastructure consists of seismic, geomagnetic and/or infrasound observatories. These observatories are key nodes in global networks of similar observatories that monitor various Earth processes and are used to provide real-time information to emergency managers and other decision makers.

Seismic monitoring: GA seismological stations in Australia's external territories form part of the Australian National Seismograph Network (ANSN), a state-of-the-art network of stations and sophisticated instrumentation that monitors natural and anthropogenic hazards in Australia and around the globe. Data from these ground stations are a key component of the regional tsunami warning network (Australian Tsunami Warning System), and support studies of continental plate motions.

Geomagnetic monitoring: GA's geomagnetic observatories monitor the Earth's continuously changing magnetic field and form part of wider Australian and international observatory networks. These observatories provide continuous, time-series data which is used in regional and global mathematical models of the geomagnetic field, space weather monitoring and scientific research. The data and information provided by geomagnetic observatories are required by international treaties to support maritime and aviation compass navigation.

Nuclear monitoring: GA's seismological and infrasound stations contribute to the global monitoring of nuclear tests. These stations are listed as part of the International Monitoring System of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) which Australia has signed and ratified. Australia's obligations under the Treaty include the establishment, operation, maintenance and upgrade of these stations, and the provision of uninterrupted data.

Current access to communications

GA's observatories utilise satellite-based communications for real-time data transfer in support of various warning services, including:

- The Joint Australian Tsunami Warning Centre (JATWC) and National Earthquake Alerts Centre (NEAC)
- Australia's commitment to the Comprehensive Nuclear-Test-Ban Treaty (CTBT)
- Space Weather Services.

These warning services require reliable, low-latency communications links from the remote observatory to the data collection and processing systems on the mainland in order to be effective. For observatories in Antarctica, this data transfer relies on satellite-based communication links supported by the Australian Antarctic Division. On other external territories, GA uses commercial satellite-based communication networks.

The communications infrastructure used to operate GA's geophysical observatories meets current needs and there is no need to increase the required bandwidth in the foreseeable future.

Recommendation 1: Maintain existing communications infrastructure in the external territories to support hazard monitoring from GA's geophysical observatories; these are key nodes in a global observatory network and are essential for:

- accurate navigation
- monitoring natural and anthropogenic hazards in Australia and around the globe and providing real-time information on hazards to help safeguard Australian and neighbouring communities
- underpinning Australia's international treaty obligations.

Positioning Infrastructure

Overview

Accurate positioning information brings increased productivity, improved community safety and boosted innovation. The reported economic benefits of these technologies have the potential to generate upward of $7.6b[1] of value over 30 years for Australia and New Zealand.

GA currently operates a network of continuously operating Global Navigation Satellite System (GNSS) reference stations across Australia and the Pacific, including stations in Antarctica (Davis, Mawson, Casey and Macquarie Island) and Australian offshore external territories (Norfolk Island, Christmas Island, Cocos (Keeling) Islands). These reference stations form part of the Australian Regional GNSS Network and the Australian Antarctic GNSS Network. Data from these stations is used for a myriad of scientific and societal applications, including monitoring the movement of the Australian and Antarctic tectonic plates and the generation of highly accurate satellite orbit and other products used globally to improve the accuracy of positioning applications.

Current access to communications

Australia is one of few countries in the world with high visibility to navigation satellite systems due to our geographic location. Each of Australia’s GNSS reference stations (including those in the external territories) record observations from the four Global Navigation Satellite Systems and two Regional Navigation Satellite Systems. For users to receive the full benefit of these observations, they need to be received by the analysis centres within two seconds of being observed. Currently this is achieved through satellite communication links. In Antarctica we share the link provided by the Australia Antarctic Division and on the other external territories we have installed our own satellite communication links. The required bandwidth over these links is minimal.

Opportunities

Through the Positioning Australia Program, GA is modernising and expanding the national network of positioning infrastructure to ensure accurate and reliable positioning services are available to all Australians. Under this program new ground stations will be installed or upgraded at some of the external territories.

Access to the highest precision positioning services (< 10 cm) typically involves the delivery of corrections over the internet. Currently these services are not available at Australia’s external territories due to limited access to fast and reliable mobile internet services. Mobile internet services relying on satellite communications are expensive. Improving mobile phone coverage in Australia’s external territories will provide competitive access to accurate and reliable positioning services. Increasing the reliability of positioning information will allow for innovation and efficiency across a range of industries such as agriculture, transport, emergency management, engineering and logistics.

Recommendation 2: Maintain and enhance existing communications infrastructure in the external territories to ensure accurate and reliable positioning services to all Australians, and boost innovation and productivity across numerous industry sectors.

[1] EY. SBAS Test-bed Demonstrator Trial Economic Benefits Report, 2019

Marine Geoscience

Overview

Australia's marine jurisdiction is about double the size of Australia's land mass and comprises four per cent of the world's oceans. With increasing global pressures on energy and food security, our marine jurisdiction is becoming increasingly important to supporting Australia's future economic growth and society well-being. GA conducts marine geoscience activities to characterise the seabed and sub-surface in the marine jurisdiction offshore Australia's external territories to support sustainable management of our marine assets and rapid growth of Australia's blue economy, worth up to $100b[2] per year. GA's seabed information supports a range of applications including:

- offshore resources, e.g. information on oil and gas resources and sites for geological carbon storage
- environmental management, e.g. marine reserves, fisheries management
- operational requirements, e.g. nautical charts, infrastructure development
- strategic national interests, e.g. definition of maritime boundaries
- scientific research, e.g. oceanography, biodiversity and climate studies
- community safety, e.g. tsunami modelling, coastal inundation.

Current access to communications

GA uses research vessels that rely on satellite-based communication systems for accurate positioning and telecommunications. Satellite communications technology varies on each vessel. Modern research vessels enable live data transfer and video streaming from the vessel. For example, Australia's blue-water research vessel, the RV *Investigator,* has a 512kbps Very Small Aperture Terminal (VSAT) data link to shore for communication services and live science data transfer. The Southern Ocean and Antarctic margin have historically been problematic regions for reliable VSAT communications.

Opportunities

Research vessels equipped with high-bandwidth satellite communication to transmit data will enable the use of telepresence technology and live data transfer. Telepresence is an efficient use of resources and is fast becoming the global standard for modern communications on blue-water research vessels. It allows unlimited access to people onshore, transcending schedules and enlisting the expertise, skills, and abilities of experts around the world who otherwise might not have the opportunity to collaborate. There are numerous benefits including:

- expanding the reach to experts without limitations of space or logistical planning that comes from transoceanic voyages
- increasing the value for money, e.g. by enabling additional or more diverse scientific activities conducted by scientists working remotely
- reduced operating costs, e.g. fewer people on board
- increasing participation and diversity, e.g. allows people to participate in voyages who are unable to go to sea
- increasing public outreach opportunities, e.g. ship-to-shore interactions with audiences at museums, aquariums, classrooms and science centres around the world.

Real-time video communications allow onshore scientists and engineers to join the voyages and provide input to enable targeted collection of biological or geological samples, identify features of interest, and troubleshoot on-board technical issues as they occur. Telepresence technology can also be used to stream

[2] National Marine Science Plan 2015–2025: Driving the development of Australia's blue economy

live video from autonomous technologies such as remotely operated vehicles (ROVs) and unmanned surface vehicles.

Access to data is immediate and sustained throughout the entire voyage, allowing for rapid turnaround from data acquisition to publication. The efficient transfer of raw data to cloud-based data warehouses enables rapid data processing and delivery of datasets for scientific analysis.

Several vessels such as the RV *Falkor* (operated by the Schmidt Ocean Institute) and the EV *Nautilus* (operated by the Ocean Exploration Trust) are already using this technology (see Appendix 1) and have demonstrated the benefits of high-bandwidth satellite communication, particularly during the current global pandemic where scientist participation on board has been limited by travel restrictions.

Recommendation 3: Enhance satellite communications technology on Australia's research vessels (RV *Investigator*, RSV *Nuyina*) to enable high reliability telepresence and data transfer when working offshore around the external territories. This will increase value for money, enhance scientific outcomes, and facilitate collection of high-quality information to support sustainable management of our marine assets and rapid growth of Australia's blue economy.

Antarctic Geoscience

Overview

GA undertakes field mapping and sampling activities in ice-free areas of Antarctica to produce geological, geomorphological and geophysical datasets to support decision-making and best-practice in environmental stewardship. Geological and geomorphological mapping is essential for landscape vulnerability and geoheritage assessments which identify and characterise fragile landforms in high-use regions near Australia's Antarctic stations and sites of intrinsic geological significance in Antarctica. These activities inform the development of appropriate environmental management and protection strategies for the Australian Antarctic Territory (AAT) under the Committee for Environmental Protection (CEP) (the body that gives effect to the principles of the Environmental Protocol to the Antarctic Treaty). GA's Antarctic field activities contribute to Australia's Antarctic mapping program and produce tangible, up-to-date map products that are an effective means to preserve Australia's interests in the AAT.

Current access

Satellite communications are used by field parties in Antarctica to provide accurate geospatial information for scientific data collection, field safety and communications, and data and information transfer to mainland Australia. This relies on satellite-based communication links supported by the Australian Antarctic Division.

Opportunities

Improved communication connections to Antarctica through high-bandwidth satellite communication would enable real-time scientific data collection, processing, and adaptation of field programs. This would support more efficient and thorough scientific programs and increase the breadth of scientific expertise that can be used in Antarctic field programs. Field parties in Antarctica could collaborate with colleagues in Australia in real-time to provide information on ground conditions and features of scientific interest. Data collected from drones and field instruments that have high computational requirements could be transferred and processed in the cloud within hours to refine and improve models and lead to more efficient field programs, e.g. identifying and filling data gaps and errors whilst still in the field.

Recommendation 4: Improve communication links to Antarctica through high-bandwidth satellite communication to improve efficiency, enhance scientific outcomes, support best-practice environmental stewardship and Australia's interests in Antarctica.

Undersea Fibre Cable to Antarctica

Earth Observations from Space

Overview

GA uses Earth observations from space (EOS), i.e. observations of Earth collected from satellites, to observe and monitor Australia, its external territories and marine jurisdiction. Satellites enable routine observation of the land, oceans, atmosphere and sub-surface, and gather information regularly across large and remote areas. There are many different types of Earth observations from space satellites including meteorological, commercial and intelligence, GA primarily focuses on land observations.

Spacecraft, generally satellites, communicate with the Earth via satellite ground stations which traditionally perform two roles:

- Downlinking the data the spacecraft is collecting (communications, Earth observation, positioning or astronomy are the four main mission types of spacecraft)
- Telemetry, Tracking and Command (TT&C) for the spacecraft

GA's Digital Earth Australia (DEA) program uses satellite data to detect physical changes across the Australian continent in unprecedented detail. DEA's satellite data platform makes it quicker and easier to access Earth observation satellite data and supports best-practice Government environmental decisions, helps Australian businesses to use satellite data and underpins the contribution of over $5b[3] annually to the Australian economy by the rapidly growing geospatial sector. The platform makes it quicker and easier to access satellite data, and this data is used to generate national products that are used to support Government priorities such as environmental monitoring (e.g. water availability) and emergency management (e.g. bushfire monitoring). These products do not currently extend to Australia's external territories, however, the potential for using EOS, particularly for environmental monitoring in Antarctica, is significant.

Current Access

GA operates Australia's only full capability satellite ground station (capable of both downlink and TT&C) in Alice Springs that hosts two 9 metre antennas, a 2.4 metre antenna, a 3 metre antenna and associated infrastructure. These antennas enable GA to collect data from a number of Earth monitoring satellites but the location means Australia can only currently receive data captured from satellites that include Australia in their orbit. GA acquires archives of the Landsat satellite series and the Sentinel satellite constellation over Australia, its external territories including Antarctica, and marine jurisdiction. The high volumes of satellite data are transferred to GA and then the relevant satellite operators via commercial fibre cables for processing, analysis and archiving.

[3] ACIL Allen. The Value of Earth Observations from Space to Australia, 2015

Opportunities

EOS is a powerful tool to support Australia's interests in Antarctica and other external territories. A satellite ground station in Antarctica with undersea fibre cable for high reliability and high-speed communications would have numerous scientific and strategic benefits.

Polar orbiting satellites are the most common types of Earth observation and positioning satellites and this orbit is being increasingly used for communications satellites. GA's satellite ground station in Alice Springs will see individual satellites twice a day but a satellite ground station in Antarctica has the potential to see every polar orbiting satellite 10-15 times a day depending on the location and satellite altitude. Therefore, Antarctica is an extremely desirable location for a satellite ground station. The evidence for this is extremely clear with many of the world's satellite ground stations currently within the Arctic Circle where fibre connections are relatively simple.

GA is currently undertaking a study into the potential for partnering with the USA (NASA and the United States Geological Survey (USGS)) on a future satellite mission as part of the planning for the Australian Government Satellite Earth Observation Roadmap led by the Australian Space Agency. The mission requires a minimum of 75 min/day of satellite visibility, with over 100 min/day considered ideal. In the analysis of the ground segment, the study explored various ground station options and found:

- Alice Springs (GA's current satellite ground station) would provide the mission with 35 min/day of satellite visibility
- Antarctica (Casey or Davis produce similar results) would provide the mission with 90 min/day of satellite visibility
- A network of satellite ground stations was required to achieve the required satellite visibility, with Antarctica representing an extremely desirable station to include within that network.

GA notes there are existing satellite ground stations in Antarctica, including the Bureau of Meteorology's satellite ground stations for meteorological data, commercial stations such as Kongsberg Satellite Services (KSAT) and satellite ground stations operated by foreign space agencies (e.g. India and China). However, for acquisition of satellite data for the purpose of land observations, a satellite ground station in Antarctica with an undersea fibre cable for high reliability and high-speed communications is required. Alternative options for higher speed data transfer and communications (e.g. small-satellite broadband links) have had limited success to date with new technologies emerging. GA has participated in discussions with the AAD and Bureau of Meteorology proposing the establishment of an undersea fibre communications cable based on multiple use-cases for high-speed data transfer between the Australian mainland and Antarctica. Ideally, an undersea cable would run from Hobart to Macquarie Island and then to mainland Antarctica.

An Australian government TT&C satellite ground station in Antarctica, connected with high speed and high reliability undersea fibre communications cable could:

- improve Australia's Earth observation data security via GA providing TT&C services to foreign space agencies (e.g. NASA, USGS, European Space Agency and UK Space Agency)
- allow greater influence of satellite scheduling over Antarctica thus leading to greater observations within the platform
- reduce the number of continental satellite ground stations required in potential future Australian satellite missions
- improve Earth observation products and services from new observations collected over Antarctica and Australia which were not previously viable due to communications bottle necks
- reduce the latency of Earth observation products and services for emergency management applications, e.g. flood and fire mapping in Australia.

New satellite observations collected over Antarctica, acquired by a satellite ground station and transferred by an undersea cable, would support development of an Antarctic-specific EOS program (e.g. Digital Earth Antarctica) to identify human impacts, track ecological changes, and identify changes to ice shelves and coastlines. This would demonstrate Australian leadership in monitoring changes in Antarctica and provide scientific information to underpin Australia's scientific and strategic interests and Antarctic Treaty obligations.

An undersea cable also offers potential for an emerging technique called "Distributed Acoustic Sensing" or DAS to be employed at the ends providing a quasi-seismic array under the sea. This approach is sometimes known as photonic seismology and has demonstrated success in earthquake detection in several studies in Europe and the USA.

The technology allows for the collection of data in areas where emplacement of traditional seismic monitoring equipment is impossible or prohibitively expensive. Current DAS systems allow for data collection up to ~40km along a fibre optic cable and provide the equivalent data of several thousand traditional seismometers. The limitations of traditional seismic monitoring technology have led to vast areas of the Earth that are sparsely monitored and result in large uncertainties in locations of seismic events and limit our understanding of the geology and geologic processes in these areas. Taking advantage of opportunities to infill the global seismic monitoring network will provide high resolution data useful for earthquake and tsunami alert services and broader geophysical research.

Undersea cables on the Antarctic continental shelf risk damage from drifting icebergs. In order to meet the reliability requirements for most satellite missions, particularly TT&C, an undersea cable would likely need to be buried and brought to shore at multiple points (e.g. Davis and Casey) with a fibre link between the landing points to provide redundancy in the case of damage from icebergs.

The viability of an undersea cable crossing the Antarctic continental shelf would need to be assessed by engineers. Further, seafloor information would be required to determine the most suitable cable route, including detailed bathymetry information (currently lacking around much of the Antarctic margin). This data would provide understanding of the seafloor morphology and dynamics and identify areas where icebergs become grounded or scrape the seafloor. This information could be collected using the new icebreaker (RSV *Nuyina*) and GA is well placed to conduct these surveys and provide the expert data analysis and interpretation.

The connection of an undersea cable to Australia (e.g. Tasmania) will also require information regarding existing use and relevant physical characteristics of the marine area, e.g. the location of existing cables, shipping, fishing activities, and oil and gas infrastructure, water depth, ocean conditions and hazards. GA's georegulation capability maintains and delivers the digital framework of maritime boundaries and regulatory zones used to administer Australia's offshore jurisdiction (Geographic Regulation), and coordinates access to the information required to support Government planning, administration and offshore economic development.

A further consideration is the inclusion of an Antarctic satellite ground station within a space park (i.e. co-location of multiple satellite ground stations). This could provide numerous benefits, including:

- streamlined approval processes for planning, spectrum management, critical infrastructure and national security concerns with ready to use high speed, high reliability communications links existing at the site
- potentially attracting significant foreign investment
- making Public Private Partnerships more likely to subsidise the ongoing cost of the cable via commercial communications revenue from hosted stations at the space park.

Recommendation 5: Investigate the viability of an undersea fibre communications cable to Antarctica, including the following planning activities:

a. an engineering study to investigate the viability of establishing an undersea cable from Australia to Antarctica
b. detailed bathymetry surveys of the Antarctic continental shelf offshore Casey and Davis stations to identify potential cable routes
c. consultation with GA to access information regarding existing use and physical characteristics of the Australian marine jurisdiction
d. assessment of the value proposition of an undersea cable to Antarctica including exploring the option of an Antarctic space park to potentially lower the cost of the cable via a Public Private Partnership.

An undersea cable to Antarctica is the key to a full capability satellite ground station and would demonstrate Australian leadership and innovation in Antarctica.

Recommendation 6: If an undersea fibre communications cable is found to be viable:

a. develop an Antarctic satellite ground station to further support the polar orbiting Earth observation satellite missions, increase the availability of satellite data for environmental decision-making, boost growth of Australia’s geospatial sector and potentially attract foreign investment.
b. develop a quasi-seismic array at the ends of the cable to improve earthquake and tsunami alert services and enhance community safety.

Appendix 1

RV *Falkor* Internet Connectivity

Information from: https://schmidtocean.org/technology/internet-connectivity/

One of R/V Falkor's most useful tools is internet access made possible by a satellite connection. High above Falkor's decks are two prominent white domes, which house the satellite antennas that enable internet at sea. The antennas are part of a unit known as VSAT – a Very Small Aperture Terminal.

How does VSAT work?

R/V Falkor's VSAT is a pair of two-way stabilized maritime antennas with a dish antenna (the "very small" aspect is because the dish is smaller than 3 meters).The dishes are enclosed in the fiberglass domes to protect them from ocean conditions while still allowing the antenna to transmit and receive. Falkor uses a Seatel 97 series marine stabilized antenna system on C Band, the original frequency allocation for communications satellites. C-band is typically used by ships that traverse the oceans regularly, requiring uninterrupted and dedicated connectivity as they move from region to region.

Falkor's VLAN system can:

- Maximize the speed and efficiency of applications over the network with traffic-shaping/ WAN optimization technologies
- Automatic report delivery and real-time monitoring
- Private, secure VPN tunnel between ship and shore
- Live acquisition to SOI Website and science sensors in real time

How do the VSATs access satellites?

VSATs access satellites in geosynchronous orbit to relay data – this means the satellite orbits Earth at the same speed as the planet is turning, enabling the satellite to stay in place over a single location. Since a ship at sea shifts with the ocean's movement, the antenna needs to be stabilized. Using a combination of GPS sensors and gyroscopes, a motorized system controls the azimuth, elevation, and skew of the antenna, so that it will be constantly pointing at the satellite it uses to transmit and receive signals.

As line of sight connection is very important for connectivity, nothing can be in the way of the satellite and the VSAT. Out on the open sea, this is rarely an issue. Normally Falkor will never have a "shadow area," but occasionally some of the courses affect the dish and the satellite. When that happens, the advantage of having two antenna kicks in – an Arbitrator moves the connection from one antenna to another, tracking the satellites and keeping the connection.

How is bandwidth distributed on Falkor?

To distribute bandwidth, Schmidt Ocean Institute has set up over 15 Virtual Local Area Networks (VLAN) for different devices and users to access. A VLAN is a system that is partitioned and isolated in a computer network at the data link layer. This means there are different segments dedicated to different missions, each with allocations and protocols to interpret supply/demand of bandwidth. With a limited amount of bandwidth, management is incredibly important. The system is smart as well, giving priority not just based on which VLAN you are connected to but your credentials and where you are. When a video presentation occurs on board, the network orchestrator detects the location and knows to allocate bandwidth appropriately.

Internet Specifications:

- VSAT System, two antennas
- Seatel 97 series
- Operating on C Band

Video Router & Streaming Specifications:

- 64 Port HD Digital Matrix enable video routing from 64 sources to 64 Monitors
- Internal streaming to Android and IOS devices
- Modulation over ATSC (Advanced Television Systems Committee) to any TV or projector on Falkor
- Customizable layout for all outputs depending on cruise objectives
- Two encoders for live streaming from any of the video router sources
- Conference room to broadcast presentation and support for video conference calls

EV *Nautilus* Telepresence

Information summarised from: https://nautiluslive.org/tech/telepresence

How Does it Work?

Nautilus utilizes telepresence technology to stream live video from remotely operated vehicles (ROVs) and various locations aboard the ship to viewers of the *Nautilus* Live website. The ship is equipped with a high-bandwidth satellite communication system that can transmit data to an unlimited number of viewers ashore. *Nautilus* is outfitted with a satellite dish that sends real-time data and video to our shore-based telepresence hub – or “mission control” – at the Inner Space Center (ISC) at the University of Rhode Island. High-definition video feeds are streamed directly from cameras aboard ROVs and up a fiber optic cable to the control van aboard the ship. These feeds are then sent from our dish to a satellite and down to a receiving station at ISC, which is connected to high-bandwidth internet that allows for the live stream of video, audio, and data to flow from ship to shore where it is captured, displayed, and disseminated in real-time. From there, video and data are distributed directly to scientists’ computers and the internet for the public. The facility also hosts teams of scientists and engineers during operations so that they can communicate with their counterparts at-sea and monitor the expedition.

Telepresence Technology

- VSAT: 2.4 meter stabilized Sea Tel 9711 uplink antenna capable of C- and Ku-band operation of up to 20 Mbps (C-band circular or linear)
- REAL-TIME VIDEO STREAMING: 6 Haivison X Encoders streaming live video via satellite to the Inner Space Center ashore (including spares)
- CAMERAS: 15 high-definition pan/tilt/zoom cameras: aft deck and port rail; Command Center; wet lab; ROV hangar; winch hold

Communications

- Ship-wide RTS Telex intercom system for shipboard communications and connection with shoreside participants
- Telephone interface is available through a Rhode Island exchange for real-time collaboration between scientists ashore and on the ship
- Full Internet connectivity from shipboard LAN and wifi
- KVH TracPhone-v7 for redundant bridge communication, providing telephone and IP service