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Guidelines for control and optimisation of hard/software

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	Name	**Organisation**	**Date**
Coordinator	Aodhán Fitzgerald	Marine Institute	29/02/2020
Activity Coordinator	Mark Elliott	Voyager IP	29/02/2020
WP Leader	ARTURO CASTELLON MASALLES	CISC	29/02/2020
Task Leader	Dick M.A. Schaap	MARIS	13/03/2020

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Glossary of Terms

Term	Description
AES 256 Encryption-	The Advanced Encryption Standard, also known by its original name Rijndael, is a specification for the encryption of electronic data.
Bandwidth Management -	Bandwidth management is the process of measuring and controlling the communications on a network link, to avoid filling the link to capacity or overfilling the link, which would result in network congestion and poor performance of the network.
Bandwidth -	Is the range of frequencies over which a system produces a specific level of performance, or the medium on which data information travels from end to end.
Beam (Spot Beam) -	A spot beam, or beam, is a directive of radio signals that is directed towards a specific area on the Earth's surface. Spot beams are also used in telecommunications for direct links between a specific satellite and a specific transponder
CIR bandwidth-	Committed Information Rate is related to the guaranteed down- and upload speed of data. This depends as well on the number of vessels in the same region sharing the same VSAT data bundle.
ComReg –	Irish communications regulator.
Footprint –	Is the area of coverage on earth a transponder can service. It also determines the size of antenna required by the end user based on the position within the footprint.
KA Satellite Service -	KA Satellite Service - The KA band is a portion of the microwave part of the electromagnetic spectrum defined as frequencies in the range 26.5–40 GHz. It is a new service that allows remotes to move between transponder beams seamlessly. KA re-uses radio frequencies in multiple beams.
Ku Satellite Service -	The Ku band is a portion of the electromagnetic spectrum in the microwave range of frequencies ranging from 11.7 to 14.5GHz. Ku uses one larger footprint to service multiple remotes.
LAN	Local area network
Link Budget	is an accounting of all the gains and losses from the teleport, through the medium (free space, cable, equipment, etc) to the remote antenna in a telecommunication system.
LTE	Is an abbreviation for Long Term Evolution. LTE is a 4G wireless communications standard developed by the 3rd Generation Partnership Project (3GPP) that's designed to provide up to 10x the speeds of 3G networks for mobile devices such as smartphones, tablets, netbooks, notebooks and wireless hotspots
MIR bandwidth-	Maximum Information Rate is related to the down- and upload speed of data, as agreed in your VSAT subscription. This depends also on the -optional selected- CIR bandwidth.
OpenAMIP	OpenAMIP is an IP based protocol that facilitates the exchange of information between an Antenna Controller Unit and a satellite modem, or remote.
Remote -	Term used for the end terminal on a satellite communications link.
Satellite Modem	A satellite modem or sat modem is a modem used to establish data transfers using a communications satellite as a relay. A satellite modem's main function is to transform an input bitstream (computer data) to a radio signal and vice versa.

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Teleport – A	teleport is a satellite ground station that functions as a hub connecting a satellite with a terrestrial telecommunications network, such as the Internet.
Transponder -	A transponder is the element of the satellite that receives and transmits radio signals at a prescribed frequency range. After receiving the signal, it will at the same time broadcast the signal at a different frequency to the teleport.
VLAN	A virtual LAN (VLAN) is any broadcast domain that is partitioned and isolated in a computer network at the data link layer (OSI layer 2).
VoIP -	Voice over Internet Protocol, also called IP telephony, is a methodology and group of technologies for the delivery of voice communications and multimedia sessions over Internet Protocol networks, such as the Internet.
VPN -	A virtual private network extends a private network across a public network, and enables users to send and receive data across shared or public networks as if their computing devices were directly connected to the private network
WAN bonding –	Also known as WAN aggregation and link load balancing, focuses on the Internet facing connections. It also improves application reliability by avoiding network failures when a link goes down, or a router fails, using multiple routes access.
WAN	Wide area network

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1 Introduction

There is a requirement to shorten the time period between data acquisition and data access for users on research vessels and on shore, as well as for interacting with crew and vessel's from the shore. The ability to directly communicate from the shore with the ship, its crew, and its data acquisition operations, while sometimes at the other end of the world, will facilitate optimising the scientific output of these costly operations and the logistic support, where needed.

Telecommunications is developing fast and so-called 'telepresence' might soon come in reach of several vessel operators. During the Eurofleets+ project some pilots will be undertaken with telepresence and real-time data transfer. This will provide further insights for possible solutions for telepresence and real-time data transfer. This deliverable undertakes to outline the guidelines for the control and optimisation of hardware and software so that these pilots can be facilitated.

As part of Deliverable 3.4 a full review of the current communication capabilities of the Eurofleets+ fleet has been conducted, to establish the technology being utilized, and to make recommendations on how the fleet can manage communications in a more effective and efficient manner.

2 Discovery

The first task undertaken in this deliverable was to conduct some discovery research across the entire Eurofleets+ project fleet to determine what communication technology individual vessels were utilising, and whether vessels are managing their requirements in a best practice manner.

The survey research indicates that gaps in knowledge and understanding for modern evolving satellite communications exist. The survey was designed in such a way to enable respondents to give a simple outline of the technology available on board the fleet. With two thirds of the fleet responding to the survey it was discovered that:

1: 69% of the fleet surveyed have VSAT services on board

2: 88% have cellular services on board

3: 56% have bandwidth management

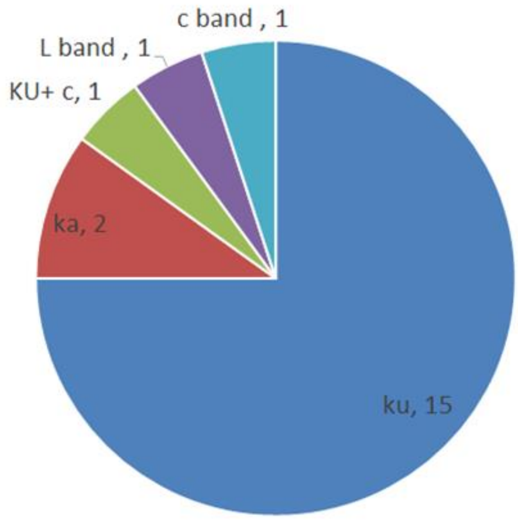

Figure 1 Current EF+ Status (system Type

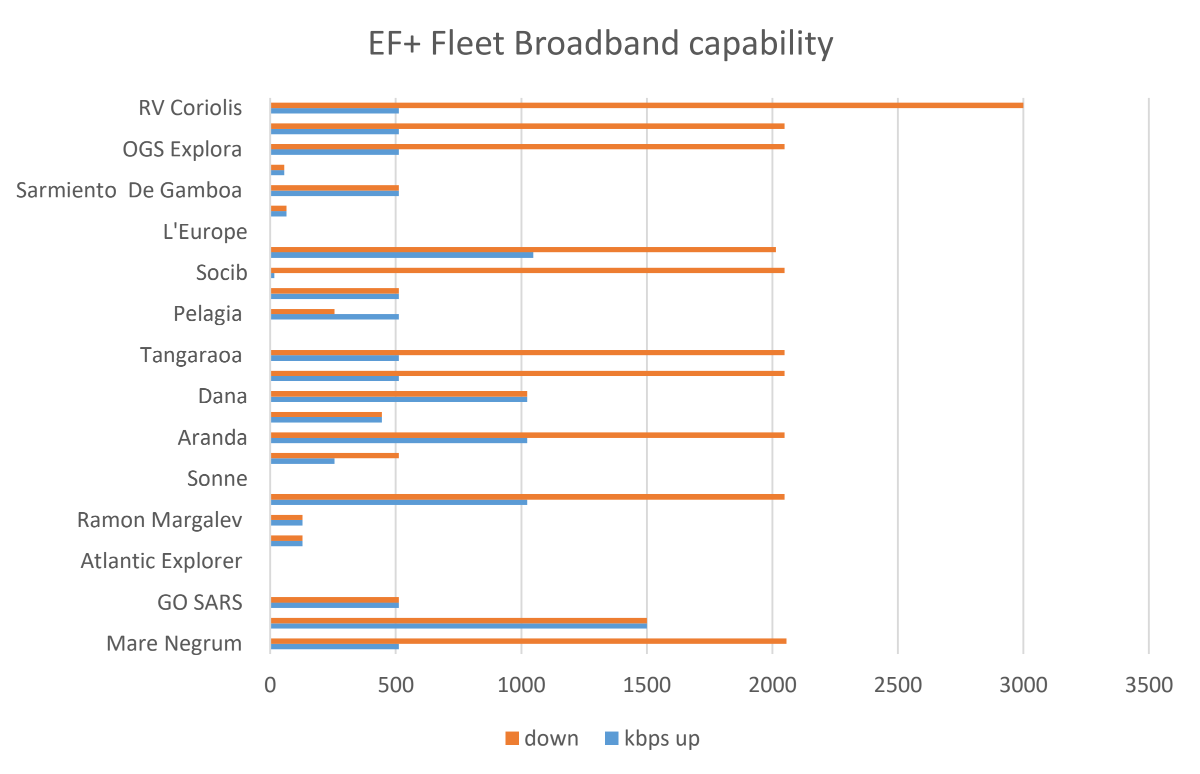

Figure 2 Bandwidth available (2018)

The planned pilot will be conducted using the VSAT telepresence unit which is included in the Marine Equipment offering of the Eurofleets+ project. This system allows for the dissemination of video, audio, and other data to be uploaded in near real time from ship to shore via the internet. This capability, called "telepresence," enables unprecedented virtual access to Remotely Operated Vehicle (ROV) dives and other activities, and two-way communication from ship to shore. The result of this is that an unlimited number of science participants can be engaged in an expedition, thus decreasing the resources required to send multiple people to sea. The public can also experience what it's like to be part of an oceanographic expedition. The system can be configured to upload multiple high-definition video with band rates as high as 20 Mbps and can operate on Ku-band and C-band frequencies. This deliverable sets out the options, challenges and recommendations to optimise the opportunity which telepresence offers.

Following a review of the Eurofleets+ fleet and Marine Equipment requirements it has been concluded that: VSAT services can be delivered in a more economic and efficient manner to the fleet.

This deliverable examines communication options available to 'at sea craft', the challenges associated with these options, and the technology required to implement a best practice approach to managing bandwidth across multiple associated vessels.

3 Proposed communications options

Communications systems that work on land are not compatible with working at sea. Fortunately, we are in an era where enhanced marine satellite communications are the answer for the maritime industry. These communications systems have become mission critical in recent years, allowing

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offshore connectivity on a continuous basis from the casual leisure boat up to the most sophisticated cruise ships.

From the offset of marine satellite communications in the late 1970's vast strides of progress have allowed the marine industry enjoy connectivity while offshore very similar to land-based terminals. A VSAT antenna housed in a radome that can rotate across 3 axis and track a satellite while the platform is moving can provide a constant connection to the internet and related services in the same fashion as a terrestrial land-based antenna.

Enhancement of these satellite communications systems comes in the form of alternative connection options, such as 4G, that gives the end user a variant of how a ship's systems connect to the world wide web. Maritime 4G systems can now reach further out to sea, and offer redundant and resilient connections, meaning a more robust overall communication gateway is available.

Utilizing Ku band VSat terminals (which is now the long-time standard), three satellite service options have been identified which are available to the Eurofleets+ group for the supply and management of satellite communications services. These VSat services, all of which can be complimented by the resilient and secure Cellular services, will provide deep sea coverage and an always on data service.

There is also the option for the newer Ka band VSat service in the applicable area of satellite coverage. This again can be complimented by a cellular service as well as offering deep sea coverage and an always on service, it must be noted that the Ka band service would have a differing footprint or area of coverage to that of Ku.

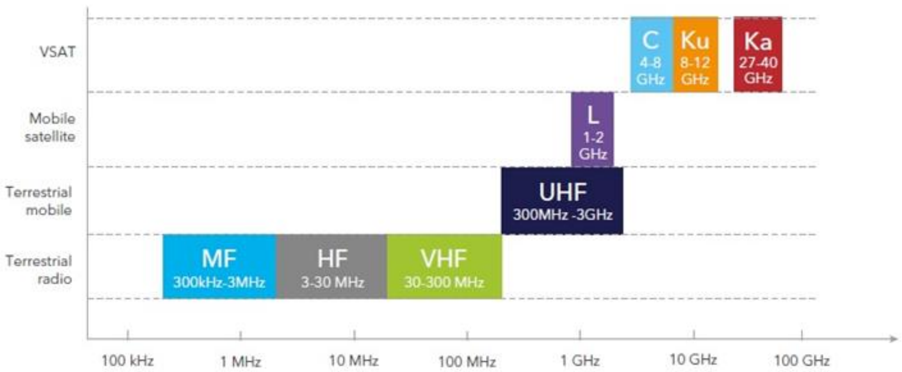

Figure 3. Frequency bands relevant for maritime communications

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Satellite service options

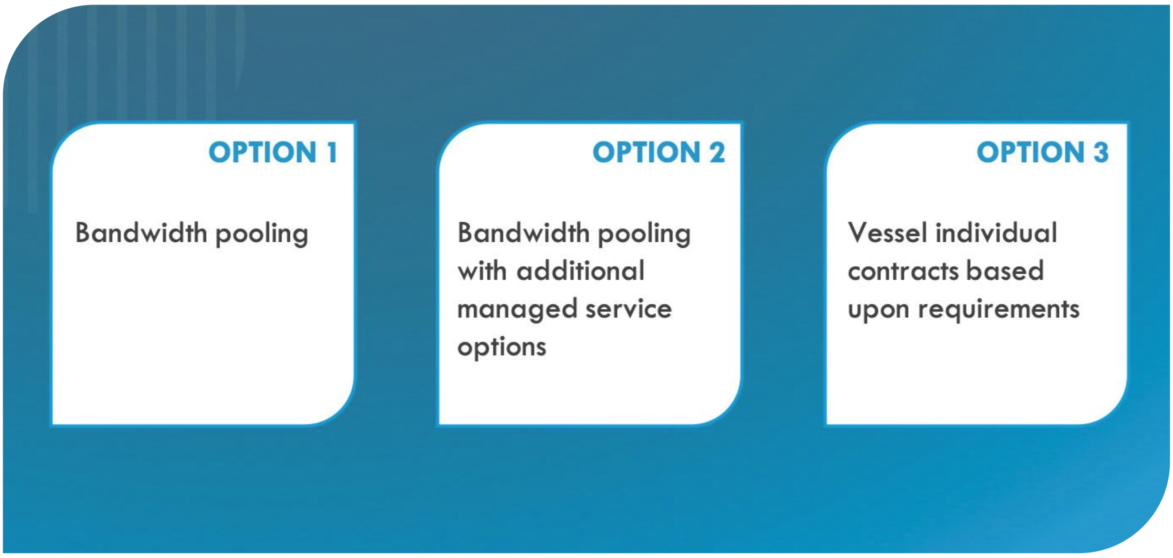

Figure 4 Satellite service profiles brief explanation

In general terms, when a satellite service profile is being applied to a vessel, a contention rate is applied unless a straight non contended service is applied.

For example, if a profile of 10Mb/2Mb on a 10: contention is applied to a modem the MIR (Maximum Information Rate) for the service is 10Mb/2Mb and the CIR (Committed Information Rate) is a division of the contention rates, in this instance 1Mb/0.2Mb. So, the guaranteed service level is 1Mb/0.2Mb and the maximum service is 10Mb/2Mb. The contention rate means this service is being shared with up to 10 other remotes. However, the other remotes may not have the same MIR or contention rate, so in turn could have a higher CIR. The higher the CIR the higher the priority is automatically assigned to the remote. Therefore, the higher MIR with contention is not always the better option to proceed with when considering communications packages. Based on this, three service options have been detailed below which are most suited to a fleet of vessels, working together with common interests and requirements, to enable telepresence.

The three service options for Ku band Vsat services are as follows:

OPTION 1: BANDWIDTH POOLING

This solution offers an overall Ku bandwidth pool, based on total fleet requirements, that all the vessels will be part of. In this scenario, all the remotes (vessels) will be active within the same satellite footprint and share a defined amount of bandwidth between them. The allocation of the bandwidth can be dynamically assigned through modulation and coding or managed based upon elements such as cruise criteria, requirements and itineraries. The flexibility that is offered in the pooled bandwidth scenario means that there is always the option to avail of the un-used bandwidth when other remotes are not utilizing it. Contention from exterior sources or vessels would not be present as the pool would be dedicated to the Eurofleets+ vessels. Added to that the dynamic allowance for temporary service upgrades in the pooled scenario means that the shared pool option for a group of vessels that wish to operate and communicate across a common platform is optimal.

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OPTION 2: BANDWIDTH POOLING WITH ADDITIONAL MANAGED SERVICE OPTIONS

This solution is a follow on from the shared KU pool of bandwidth. In this case most of the remotes would avail of the pooled bandwidth as they are operating within the same satellite footprint, but with the addition of remotes working outside the main area. In this event, Ku profiles preferably by the same provider would be allocated to these remotes and be managed individually, outside of the pool. The management of these remotes can be affected by mitigating against the shared pool size or on a solely individual basis. There would be zero service effects to the managed remotes, and cross/external communications would continue as if all the remotes were in the same pool of bandwidth.

OPTION 3: VESSEL INDIVIDUAL CONTRACTS BASED UPON REQUIREMENTS

This solution is essentially how the fleet of research vessels operate today. Each individual remote has its own defined profile or service, and across a range of service providers. While this solution is operationally acceptable it does not achieve the full flexibility and deliverables that the shared environment presents.

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KU SERVICE OPTIONS

It is recommended that Option 2 be considered as the best solution; utilization of a shared pool of Ku satellite bandwidth to service the Eurofleets+ remotes while also understanding that some of the vessels will not be geographically able to work within the same footprint. This type of solution has seen an enhanced experience for end users when operating within a shared environment enjoying the benefits such as utilization of un-used bandwidth and no contention issues in the past.

Benefits from the adaptive and dynamic nature of the bandwidth resources has led to the better experience for real time users. Bandwidth can be swiftly allocated to remotes as and when required, while vessels not on charter or on maintenance periods are not compelled to maintain VSat services, thus potentially freeing up bandwidth for operational vessels within the pool. The technical and economic benefits from a shared pool of bandwidth offers an attractive group investment option, especially when multiple vessels are involved.

When a vessel or remote is operating outside of the pooled services, managed service can be provided, where the remote will enjoy a dedicated service provision like a stand-alone service contract. However, this managed service would also be made visible along with the remotes within the pool, on the iMonitor monitoring software (explained in detail further in this document).

KA SERVICE OPTION

In recent times, circa 5 years, the KA service has come onto the marine platform. KA is a higher frequency than Ku and put simply there is more frequency available. Due to the technical ability of the satellite operators along with the co-operation of the ITU (International Telecommunications Union) frequencies can be re-used allowing multiple spot beams. What this means to the end user is a higher throughput of data, with providers currently offering up to 36Mb to the remote and higher profiles to come.

In the past there was a concern that atmospheric conditions would affect the performance of KA due to the smaller size of its propagated wavelength. Adaptive, or dynamic modulation and coding techniques are used to combat changes in conditions. As these conditions change local to the terminal (modem), such as weather fade due to adverse precipitation, the modulation and coding adjusts accordingly to compensate. Terminals in the same beam are even likely to use different modulation and coding during a weather event as the fade conditions are very localized and can vary greatly within the footprint of one beam. The adaptation is targeted to give each terminal the highest possible data rate that the link will support at those individual terminals.

Each remote receives its own service profile, which is based like that on a Ku service, in that the remote will be assigned a CIR and MIR. Since the service is in its infancy, the MIR is achievable on a near constant basis due to most marine communications platforms still utilizing the traditional KA platform. For a fleet proposal in KA, each vessel would require a simple audit to examine the conversion ability of the current satellite antenna. The main hardware providers now supply conversion kits, allowing vessels to enjoy the KA service but when planning to deploy to an area where KA is not yet available, can revert to a Ku service.

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A migration to KA satellite services provides an opportunity for the Eurofleets+ vessels to enjoy a far larger area of coverage on a single transponder with multiple seamless beam switches (see KA footprint) and with a greater throughput return for the costing.

Cellular service option

A cellular based solution is proposed to enhance the satellite communications onboard. The type of service being proposed is a system that utilizes multiple cellular SIM cards across multiple communication modules, and then bonds the results connections together to form a single connection all the while presenting the ability to use multiple SIM providers to enhance the resilience of the connection.

While any system integration aspect may appear to be challenging, we are confident the cellular bonding service can be integrated with current vessel infrastructures. This technology has been proven to mitigate against the latency issues experienced by some communications applications when relying on alternate mediums of data transfer, thus allowing researchers onboard to complete work that would normally have not been possible whilst on board.

In order to further increase the range of this service, the proposed introduction of a cellular reception booster to increase the offshore range of reception is recommended. This not only benefits the cellular bonding but also allows the use of localized antennas below decks, extending cellular reception to areas of the vessel that was previously unachievable. Devices such as single SIM personal devices on board, even below decks or mess / recreational areas, can enjoy increased reception, which will have a massive impact on crew welfare.

3. Challenges & opportunities

Modern communications through the IoT (Internet of Things) must deal with the normal associated problems while also dealing with throughput (the actual rate that information is transferred), latency (the delay between the sender and the receiver decoding it) and security criteria. Add the marine environment and budget related restrictions to the standard communications problems and we now have the regular marine communications considerations to contend.

Traditional communications now mitigate these problems by placing more emphasis on integration rather than focusing on one solution for one problem. This document brings that traditional approach to the marine environment and in turn to Eurofleets+. This approach in general terms, with the integration of several components to form a singular solution will require the participation and co-operation of several specialist disciplines. This multiple faceted approach would not only apply to the implementation phase, but would also carry through to the test and operational phase of the pilot.

An opportunity exists to create a synergistic and uniform communications platform across the Eurofleets+ project vessels. This opportunity could facilitate the ability for the necessary applications to co-habit across the fleet via a dynamic and readily accessible communications link.

The existing communications variant across the fleet is understandably vast based on the knowledge harvested to date. Vessels operate on a satellite platform or a cellular service, or in some instances a combination of both.

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To formulate a near definitive solution, a basic audit of a sample number of vessels would serve the current knowledge base, allowing the assignment of the most suitable hardware and applications to formulate a suggested infrastructure from the following resources:

The offering of two satellite-based communications mediums, a Ku and a Ka Band based solution.

The offering of an LTE / Cellular Service to compliment the Satellite connectivity when vessels are conducting operations within the enhanced cellular service range. This service will be encrypted to a minimum of AES 256 standards and allow multiple cellular / LTE carriers to be accessed simultaneously providing additional resilience.

The implementation of a WAN source selection / balancing solution to allow multiple WAN links to be facilitated when possible / necessary with no manual intervention required, seamless service provision.

Provision of an intuitive bandwidth management tool for each operational vessel with the facility of assigning bandwidth segments to a particular service, IP address, or VLAN, managing traffic types and creating rules to optimize performance of priority services.

Provision of an intuitive network monitoring service in conjunction with the ability to manage the throughput to the vessel.

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4. Suggested technologies

To seamlessly continue the current Ku service for Eurofleets+ a combination of Ku/KA could be achieved by managing the Ku pool size as the fleet of KA vessels increase should this option be preferable. A linear approach can be taken for the migration of vessels, always keeping in mind the operational requirements for each vessel.

From throughput and economic reasons, the implementation of the proven KA bandwidth is also suggested. By referring to the KA footprint provided, coverage is extended well into the western seaboard area. KA allows greater throughput availability per remote on cost in a like by like profile basis, in turn offering a better economic return.

The proposed KA model, unlike other KA services available on the market, is not restrictive in terms of route planning, the vessels are free to move within the extensive KA footprint, as supplied, seamlessly.

Operationally resilient KA/Ku solution

The ability to revert a previously converted system back to Ku when required has been demonstrated in the past, will be applied thus building contingency into the proposed model. This versatility has been proven in the past when a KA demonstration was implemented for the Irish Naval Service. During this time, the VSat unit onboard was upgraded to KA for the purpose of a demonstration before being reverted to Ku upon conclusion of the demonstration. This will provide the opportunity for the pilot to take place and provide the option to the participating vessels to revert to their original system if desired.

The suggested solution can provide the Eurofleets+ fleet with complete oversight of the VSat modems and throughput within the fleet using software which would continuously monitor the application. The software available offers visibility of each remote in the live environment.

This solution also provides the ability to interrogate the modem for historical data such as IP traffic, events and condition and alarms. IP traffic information can give the user a clear indication of the amount of traffic this is either currently passing through the modem or provide a historical grab with a pre-defined time frame. By activating the traffic legend, the end user can also see the traffic type's i.e. UDP, HTTP etc.

Events and conditions give the user information including the last GPS position received by the remote, which is critical for accurate satellite tracking. This view also presents log files of the events leading up to the rare occurrence of a remote going offline.

The error types experienced will give an indication of the cause. Alarms can be viewed live, which help assess the system performance such as losses over cables or aging hardware.

Dynamic satellite bandwidth management

The solution will provide the fleet with bandwidth increases per pool or per vessel across both KA and Ku services if required. Historically there is a limitation or restriction on such short notice increases, but with the nature of the Eurofleets+ fleet activities in mind, it is considered an important element to have available.

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Intuitive onboard bandwidth management and monitoring

The solution considered the most effective is an intuitive bandwidth management tool. A rack mountable solution can provide each research vessel with the facility of assigning bandwidth segments to a service, IP address, user group, or VLAN, managing traffic types and creating rules to optimize performance on priority services.

This type of enterprise level solution, as a bandwidth management and monitoring tool, supports the use of traffic management, such as individual VLAN's and will be able to route the traffic as required. The ability to apply bandwidth restrictions to each specific VLAN and restrict traffic from applications is available as a standard feature.

Such solutions can prioritize traffic with quality of service rules and use application control to distinguish and filter application traffic. A simple example of this in use, is the ability to allow text applications while preventing VOIP calls, on both wired and wireless networks. All the while allowing the onboard engineer the ability to monitor and manage the traffic priorities in the real time environment, along with remote support 24/7/365. The type of software also provides award winning military grade end point protection with artificial intelligence and EDR, giving unmatched defence against malware, exploits and ransomware.

Getting insight into what's happening on the wireless networks is a traditional daily struggle for many IT administrators. The software solutions available can provide access points and management, the monitoring and management aspect of the XG allows visibility of the status of the Wi-Fi networks, access points, connecting clients, and the environment to identify potential risks or inappropriate use of the vessel's resources.

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LTE/Cellular service as a data carrier

There are a number of options available on the market which will provide an effective solution. However, it is recommended that a solution which offered the option to bond SIM cards (ideally with the flexibility to bond cards from multiple suppliers) together be sourced as this will deliver a great level of resilience and security. This type of application enables the modules that house the cards bond together and the data is transferred from the router to the end hub via an encrypted VPN. Each individual SIM connection is also encrypted. This approach will result in:

- A reliable, affordable, fast, and secure connection is achieved by using either;
- A physical hub located in a central Eurofleets+ location
- A managed virtual hub with internet breakout

Deployment of the solution

A remote router is deployed on each ship, thus providing direct end to end VPN's through a singular hub in the data centre. The router's WAN bonding architecture allows bonding across several physical links into one virtual high-speed connection which is virtually always on, which provides the sum of all upstream and downstream bandwidths combined, and which provides high security since single packets are fragmented across different provider networks.

This type of VPN technology is not based on a single connection, but rather on the bonding of several Internet connections of different providers and even technologies. This type of solution will utilize existing cellular networks, once in receipt of signal, to form the WAN bonding. Several different networks can be used simultaneously.

Using specific encryption, the solution provides the highest level of security since as it takes one packet, fragments it and transmits the fragments across different links. Coupling this fragmentation with the use of 6 modules that can be from different service providers gives a heightened level of encryption beyond the AES-256 standard.

Simultaneous use of multiple lte/cellular services

Ideally the deployed solution should be able to house up to 6 modules that can each host a single SIM card. This will allow for future proofing in that modules can be removed and replaced to match the technology growth within the cellular service industry but avoiding the forklift expense.

Cellular signal enhancing solution

It is recommended that the cellular/LTE reception should be enhanced using a marine mobile signal booster ideally with multiband repeater, which is fully compliant with the communications regulator. Such units usually have an external element which consists of an antenna installed on the upper decks of a vessel which receives signal in a 360 degrees' arc. They can also receive the signal from several LTE/UMTS masts on the coastline and is non-provider specific.

A signal is sent to the deployed signal booster repeater which is usually installed below decks. The boosters have an indoor antenna attached which wirelessly transmits the cellular signal to its immediate vicinity. The deployed router unit should be housed near the antenna to avail of this signal

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enhancement. In addition to enhancing the routers signal availability, an inline repeater can be used to facilitate several indoor antennae to provide enhanced signal for personal cellular devices.

Effectively this type of solution will provide LTE/UMTS reception below deck in area's that would normally be screened by the vessels hull and thus remove the reliance on the internal WIFI internet WAN source, thus, whilst the ship is in the enhanced cellular reception area, it removes the Welfare element from reliance on the space link. It should be noted that there are marine mobile signal booster's available on the market which enhance all LTE/UMTS signals and are not physically connected to any network component onboard. These options have been detailed in the technical addendum documents where a map shows the cellular masts as per ComReg registration that a signal enhancer will receive signal from.

Automatic changeover from LTE/cellular to satellite

It is recommended for flexibility that the system facilitates the changeover to be automatically controlled via the firewall, coupled with its bandwidth management ability, or that it can be manually actioned via the user interface.

It is suggested that a priority rule be set up on the deployed bandwidth management solution to facilitate the seamless change over removing any configuration changes from existing onboard equipment. The physical (manual) selection can also take place when in cellular coverage, or reversion to the satellite.

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5. Infrastructure requirements

Existing communications systems

The proposed solution should maximize the use of all existing communications infrastructure, where Ku band VSat terminals are in existence on board they will be required to have OpenAMIP capabilities in order to facilitate automatic beam switching while on Ku service. If the systems are dated an onsite visit by a VSAT engineer can be facilitated.

Where cellular data services are already in place on board the vessel, they can be integrated within the proposed solution, and their connection details and capabilities will be scrutinized for compatibility. Should it prove to be prudent to replace the cellular hardware, then their existing antenna cabling and connections, where possible will be utilized for the proposed cellular bonding and booster systems proposed.

After an initial survey and inspection of the existing infrastructure on board and in relation to the Ku service, advice, suggestions and recommendations will be made post inspection for the infrastructure, we will however retain as much of the existing Eurofleets+ communications infrastructure where possible and retain services as necessary.

EXISTING NETWORK TOPOGRAPHY

The vessels existing wired and wireless infrastructure should remain as is and unaffected by the solution implementation, however, as with the communications systems, it would be prudent to carry out an initial survey and inspection of the existing network, both wired and wireless address any items of note, be they in an advisory or mandatory capacity.

If an existing firewall system is in place, an examination can take place for compatibility within the proposed communication framework. This would clarify the capabilities of the current hardware to comply with the suggested level of traffic management, monitoring and selection ability as detailed. This device should allow for the collection of all WAN media sources into one selection application to allow for seamless transition between WAN routes for the vessel network.

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6 Service provision

How the internet will be provisioned in the solution?

A specific Internet Service Provider will be sourced to provide the satellite provision required to carry out the pilot. However, as the project has a global presence ISP partner's, alternative locations will be provided.

Technical training

With the deployment of the new equipment and software, training would need to be provided to crew for both the remote routers onboard ship and for the hub should one be selected.

7 Potential space segment delivery

Proposed transponder footprint coverage

This concept, as an example, covers the Western Atlantic and beyond, and the Mediterranean Sea in full by both the primary Ku platform and back up beams. In this example Thor 5 would form the primary beam for the shared Ku bandwidth pool. The composite Ku (Fig 5) footprint included here shows the coverage combined of all the Ku platforms available in this instance. Global coverage outside of the Eurofleets+ normal area of operation is also available on a case by case basis.

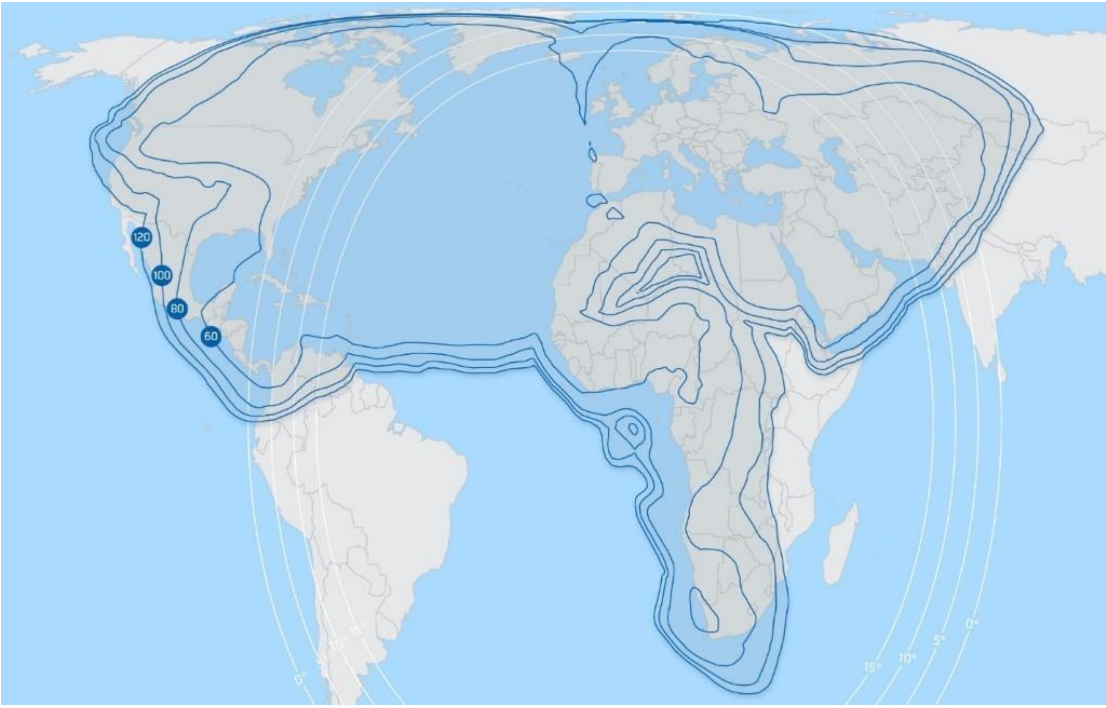

Figure 5 The above footprint shows the coverage available on the KA platform.

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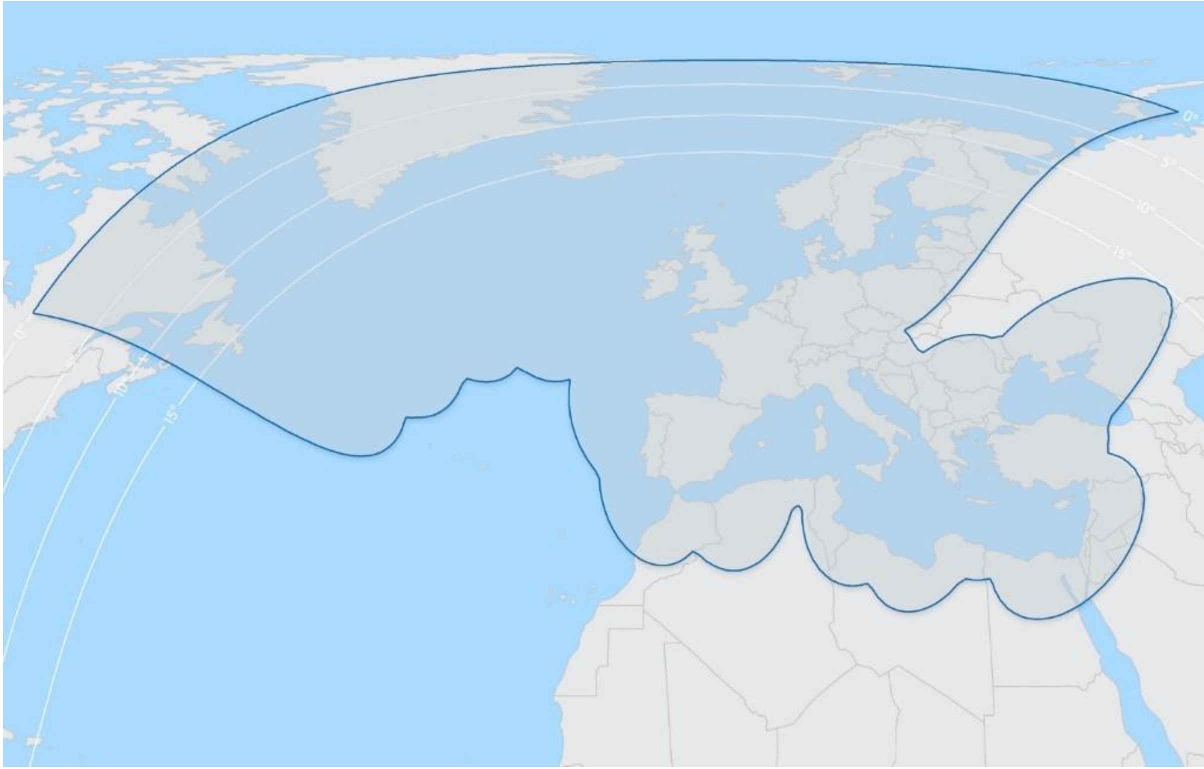

Figure 6 The above footprints are examples of the satellite footprints that would pre dominantly cover Eurofleets+ vessel areas of operation.

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8 Recommendations

On consideration of all parameters to deliver VSAT services in a more economic and efficient manner to the Eurofleets+ fleet the proposed solution is a co-operative type solution with a shared pool of Ku satellite bandwidth for Eurofleets+, to maximise the best potential for communications.

This would involve a collaborative approach in working towards a common communications platform for the fleet.

Elements of this suggestion include the understanding of the actual communications requirements for the operational applications and working with the software architects to derive the throughput thresholds required along with the demonstration of a common communications platform across several Eurofleets+ vessels.

For the demonstration no less than 3, preferably 5 or more, vessels within a purposely constructed shared bandwidth pool would provide the ideal knowledge base and demonstrative results for a definitive plan of progress.

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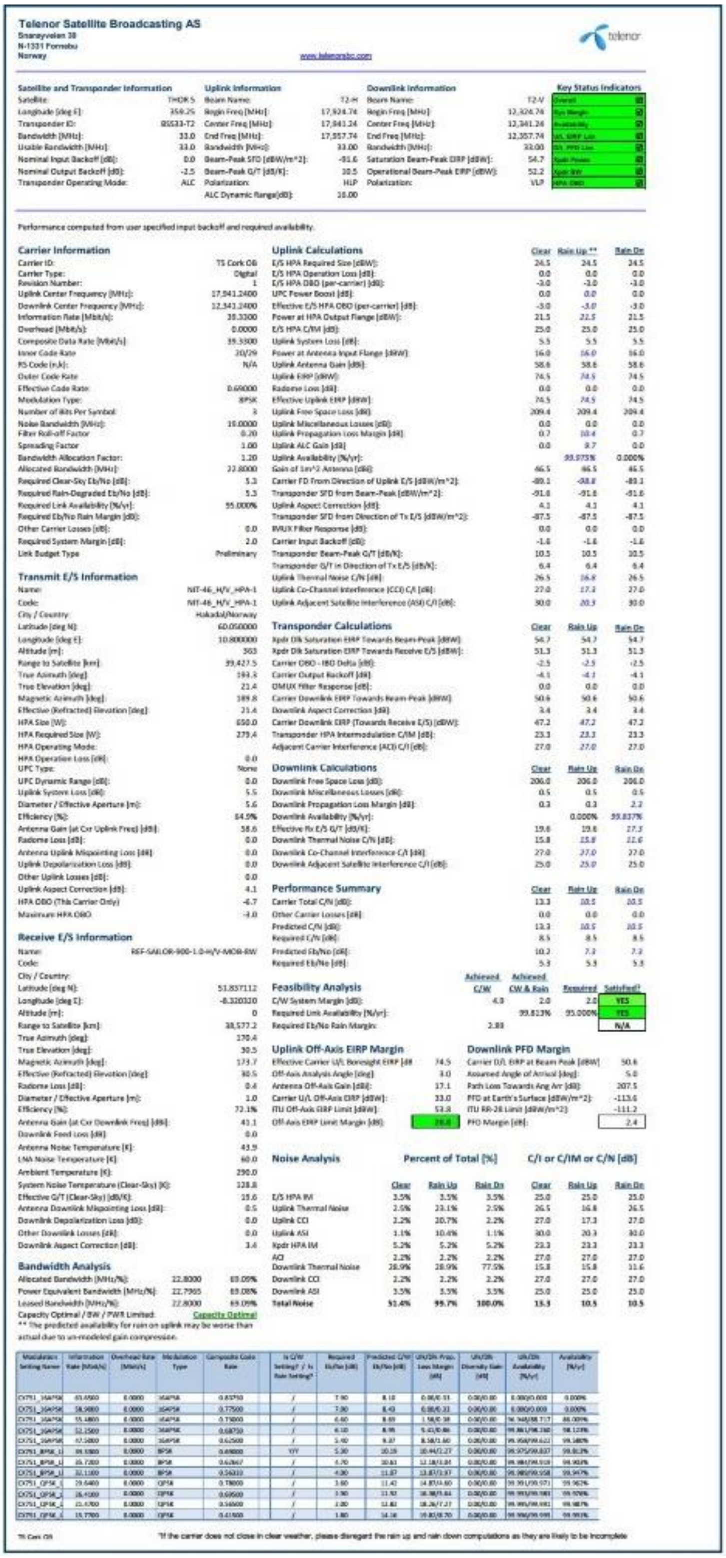
APPENDIX I

A satellite communication network consists of several earth stations inter-connected via a satellite. The radio links used for interconnections are designed to deliver messages at the destination with acceptable fidelity. A compromise is exercised between the quality and quantity of delivered messages and practical constraints such as economics and the state of technology.

To deliver a large amount of information at a very high quality may require unacceptably high cost. Factors which need consideration in a link design include operational frequency, propagation effects, acceptable spacecraft/ground terminal complexity (hence cost), effects of noise and regulatory requirements.

All these factors are considered when compiling what is known as satellite the link budget. A minimum tolerance is derived that the link must meet before the satellite owners will operationally activate the link. See below some link budget examples.



Telenor Satellite Broadcasting AS
Snarøyveien 30
N-1331 Fornebu
Norway

Satellite and Transponder Information		Uplink Information	
Satellite:	THOR 5	Beam Name:	72-H
Longitude [deg E]:	359.25	Begin Freq [MHz]:	17,924.74
Transponder ID:	BSS33-T2	Center Freq [MHz]:	17,941.24
Bandwidth [MHz]:	33.0	End Freq [MHz]:	17,957.74
Usable Bandwidth [MHz]:	33.0	Bandwidth [MHz]:	33.00
Nominal Input Backoff [dB]:	0.0	Beam-Peak SFD [dBW/m^2]:	-81.6
Nominal Output Backoff [dB]:	-2.5	Beam-Peak G/T [dB/K]:	10.5
Transponder Operating Mode:	ALC	Polarization:	HLP
		ALC Dynamic Range[dB]:	18.00

Performance computed from user specified input backoff and required availability.

Telenor Satellite Broadcasting AS
Snarøyveien 30
N-1331 Fornebu
Norway

www.telenorsbc.com

Satellite and Transponder Information		Uplink Information		Downlink Information		Key Status Indicators
Satellite:	IS-10-02	Beam Name:	S1D	Beam Name:	S1D	Overall ☑
Longitude [deg E]:	359.00	Begin Freq [MHz]:	14,379.00	Begin Freq [MHz]:	11,579.00	Sys Margin ☑
Transponder ID:	69/69	Center Freq [MHz]:	14,435.00	Center Freq [MHz]:	11,635.00	Availability ☑
Bandwidth [MHz]:	112.0	End Freq [MHz]:	14,491.00	End Freq [MHz]:	11,691.00	DL EIRP Lim ☑
Usable Bandwidth [MHz]:	112.0	Bandwidth [MHz]:	112.00	Bandwidth [MHz]:	112.00	DL PFD Lim ☑
Nominal Input Backoff [dB]:	-5.1	Beam-Peak SFD [dBW/m^2]:	-86.9	Saturation Beam-Peak EIRP [dBW]:	54.2	Xpdr Power ☑
Nominal Output Backoff [dB]:	-3.0	Beam-Peak G/T [dB/K]:	6.9	Operational Beam-Peak EIRP [dBW]:	51.2	Xpdr BW ☑
Transponder Operating Mode:	FGM	Polarization:	HLP	Polarization:	VLP	HPA OBO ☑
		ALC Dynamic Range(dB):				

Power computed from user required Eb/No and required availability.

Carrier Information

Carrier ID:	TS Cork IB
Carrier Type:	Digital
Revision Number:	1
Uplink Center Frequency [MHz]:	14,435.0000
Downlink Center Frequency [MHz]:	11,635.0000
Information Rate [Mbit/s]:	1.3200
Overhead [Mbit/s]:	0.0000
Composite Data Rate [Mbit/s]:	1.3200
Inner Code Rate:	3/4
RS Code (n,k):	N/A
Outer Code Rate	
Effective Code Rate:	0.75000
Modulation Type:	QPSK
Number of Bits Per Symbol:	2
Noise Bandwidth [MHz]:	0.8800
Filter Roll-off Factor	0.20
Spreading Factor	1.00
Bandwidth Allocation Factor:	1.20
Allocated Bandwidth [MHz]:	1.0560
Required Clear-Sky Eb/No [dB]:	4.2
Required Rain-Degraded Eb/No [dB]:	4.2
Required Link Availability [%/yr]:	95.000%
Required Eb/No Rain Margin [dB]:	
Other Carrier Losses [dB]:	0.0
Required System Margin [dB]:	2.0
Link Budget Type	Preliminary

Transmit E/S Information

Name:	REF-SAILOR-900-1.0-H/V-MOB-BW
Code:	
City / Country:	
Latitude [deg N]:	51.837112
Longitude [deg E]:	-8.320320
Altitude [m]:	0
Range to Satellite [km]:	38,574.7
True Azimuth [deg]:	170.7
True Elevation [deg]:	30.5
Magnetic Azimuth [deg]:	174.0
Effective (Refracted) Elevation [deg]:	30.5
HPA Size [W]:	8.0
HPA Required Size [W]:	3.1
HPA Operating Mode:	
HPA Operation Loss [dB]:	0.0
UPC Type:	None
UPC Dynamic Range [dB]:	0.0
Uplink System Loss [dB]:	0.5
Diameter / Effective Aperture [m]:	1.0
Efficiency [%]:	61.2%
Antenna Gain (at Cxr Uplink Freq) [dBi]:	41.7
Radome Loss [dB]:	0.5
Antenna Uplink Mispointing Loss [dB]:	0.5
Uplink Depolarization Loss [dB]:	0.0
Other Uplink Losses [dB]:	0.0
Uplink Aspect Correction [dB]:	1.5
HPA OBO (This Carrier Only)	-5.1
Maximum HPA OBO	-1.0

Receive E/S Information

Name:	NIT-46_H/V_HPA-1
Code:	NIT-46_H/V_HPA-1
City / Country:	Hakadal/Norway
Latitude [deg N]:	60.050000
Longitude [deg E]:	10.800000
Altitude [m]:	363
Range to Satellite [km]:	39,430.6
True Azimuth [deg]:	193.6
True Elevation [deg]:	21.3
Magnetic Azimuth [deg]:	190.1
Effective (Refracted) Elevation [deg]:	21.4
Radome Loss [dB]:	0.0
Diameter / Effective Aperture [m]:	5.6
Efficiency [%]:	59.6%
Antenna Gain (at Cxr Downlink Freq) [dBi]:	54.4
Downlink Feed Loss [dB]:	0.3
Antenna Noise Temperature [K]:	45.0
LNA Noise Temperature [K]:	65.0
Ambient Temperature [K]:	290.0
System Noise Temperature (Clear-Sky) [K]:	126.3
Effective G/T (Clear-Sky) [dB/K]:	33.2
Antenna Downlink Mispointing Loss [dB]:	0.0
Downlink Depolarization Loss [dB]:	0.0
Other Downlink Losses [dB]:	0.0
Downlink Aspect Correction [dB]:	1.0

Bandwidth Analysis

Allocated Bandwidth [MHz/%]:	1.0560	0.94%
Power Equivalent Bandwidth [MHz/%]:	0.1615	0.14%
Leased Bandwidth [MHz/%]:	1.0560	0.94%
Capacity Optimal / BW / PWR Limited:		**BW Limited**

** The predicted availability for rain on uplink may be worse than actual due to un-modeled gain compression.

Uplink Calculations

	Clear	Rain Up **	Rain Dn
E/S HPA Required Size [dBW]:	5.0	5.0	5.0
E/S HPA Operation Loss [dB]:	0.0	0.0	0.0
E/S HPA OBO (per-carrier) [dB]:	-1.0	-1.0	-1.0
UPC Power Boost [dB]:	0.0	0.0	0.0
Effective E/S HPA OBO (per-carrier) [dB]:	-1.0	-1.0	-1.0
Power at HPA Output Flange [dBW]:	4.0	4.0	4.0
E/S HPA C/IM [dB]:	25.0	25.0	25.0
Uplink System Loss [dB]:	0.5	0.5	0.5
Power at Antenna Input Flange [dBW]:	3.5	3.5	3.5
Uplink Antenna Gain [dBi]:	41.7	41.7	41.7
Uplink EIRP [dBW]:	45.2	45.2	45.2
Radome Loss [dB]:	0.5	0.5	0.5
Effective Uplink EIRP [dBW]:	44.7	44.7	44.7
Uplink Free Space Loss [dB]:	207.4	207.4	207.4
Uplink Miscellaneous Losses [dB]:	0.5	0.5	0.5
Uplink Propagation Loss Margin [dB]:	0.4	0.8	0.4
Uplink ALC Gain [dB]:	0.0	0.0	0.0
Uplink Availability [%/yr]:		95.240%	0.000%
Gain of 1m^2 Antenna [dBi]:	44.6	44.6	44.6
Carrier FD From Direction of Uplink E/S [dBW/m^2]:	-118.9	-119.3	-118.9
Transponder SFD from Beam-Peak [dBW/m^2]:	-86.9	-86.9	-86.9
Uplink Aspect Correction [dB]:	1.5	1.5	1.5
Transponder SFD from Direction of Tx E/S [dBW/m^2]:	-85.4	-85.4	-85.4
IMUX Filter Response [dB]:	0.0	0.0	0.0
Carrier Input Backoff [dB]:	-33.5	-33.9	-33.5
Transponder Beam-Peak G/T [dB/K]:	6.9	6.9	6.9
Transponder G/T in Direction of Tx E/S [dB/K]:	5.4	5.4	5.4
Uplink Thermal Noise C/N [dB]:	11.0	10.5	11.0
Uplink Co-Channel Interference (CCI) C/I [dB]:	27.0	26.6	27.0
Uplink Adjacent Satellite Interference (ASI) C/I [dB]:	30.0	29.6	30.0

Transponder Calculations

	Clear	Rain Up	Rain Dn
Xpdr Dlk Saturation EIRP Towards Beam-Peak [dBW]:	54.2	54.2	54.2
Xpdr Dlk Saturation EIRP Towards Receive E/S [dBW]:	53.2	53.2	53.2
Carrier OBO - IBO Delta [dB]:	2.1	2.1	2.1
Carrier Output Backoff [dB]:	-31.4	-31.8	-31.4
OMUX Filter Response [dB]:	0.0	0.0	0.0
Carrier Downlink EIRP Towards Beam-Peak [dBW]:	22.8	22.4	22.8
Downlink Aspect Correction [dB]:	1.0	1.0	1.0
Carrier Downlink EIRP (Towards Receive E/S) [dBW]:	21.8	21.3	21.8
Transponder HPA Intermodulation C/IM [dB]:	14.5	14.1	14.5
Adjacent Carrier Interference (ACI) C/I [dB]:	27.0	26.6	27.0

Downlink Calculations

	Clear	Rain Up	Rain Dn
Downlink Free Space Loss [dB]:	205.7	205.7	205.7
Downlink Miscellaneous Losses [dB]:	0.0	0.0	0.0
Downlink Propagation Loss Margin [dB]:	0.4	0.4	1.6
Downlink Availability [%/yr]:		0.000%	99.748%
Effective Rx E/S G/T [dB/K]:	33.2	33.2	31.5
Downlink Thermal Noise C/N [dB]:	18.0	17.6	15.1
Downlink Co-Channel Interference C/I [dB]:	27.0	26.6	27.0
Downlink Adjacent Satellite Interference C/I [dB]:	25.0	24.6	25.0

Performance Summary

	Clear	Rain Up	Rain Dn
Carrier Total C/N [dB]:	8.4	8.0	8.0
Other Carrier Losses [dB]:	0.0	0.0	0.0
Predicted C/N [dB]:	8.4	8.0	8.0
Required C/N [dB]:	6.0	6.0	6.0
Predicted Eb/No [dB]:	6.6	6.2	6.2
Required Eb/No [dB]:	4.2	4.2	4.2

Feasibility Analysis

	Achieved C/W	Achieved CW & Rain	Required	Satisfied?
C/W System Margin [dB]:	2.4	2.0	2.0	YES
Required Link Availability [%/yr]:		95.001%	95.000%	YES
Required Eb/No Rain Margin:	0.41			N/A

Uplink Off-Axis EIRP Margin

Effective Carrier U/L Boresight EIRP [dB	44.7
Off-Axis Analysis Angle [deg]:	3.0
Antenna Off-Axis Gain [dBi]:	17.1
Carrier U/L Off-Axis EIRP [dBW]:	20.0
ITU Off-Axis EIRP Limit [dBW]:	40.5
Off-Axis EIRP Limit Margin [dB]:	20.5

Downlink PFD Margin

Carrier D/L EIRP at Beam Peak [dBW]	22.8
Assumed Angle of Arrival [deg]:	5.0
Path Loss Towards Ang Arr [dB]:	206.9
PFD at Earth's Surface [dBW/m^2]:	-141.3
ITU RR-28 Limit [dBW/m^2]:	-126.6
PFD Margin [dB]:	14.8

Noise Analysis

	Percent of Total [%] Clear	Rain Up	Rain Dn	C/I or C/IM or C/N [dB] Clear	Rain Up	Rain Dn
E/S HPA IM	2.0%	2.0%	2.0%	25.0	25.0	25.0
Uplink Thermal Noise	50.2%	55.3%	50.2%	11.0	10.5	11.0
Uplink CCI	1.2%	1.4%	1.2%	27.0	26.6	27.0
Uplink ASI	0.6%	0.7%	0.6%	30.0	29.6	30.0
Xpdr HPA IM	22.4%	24.6%	22.4%	14.5	14.1	14.5
ACI	1.2%	1.4%	1.2%	27.0	26.6	27.0
Downlink Thermal Noise	10.0%	11.0%	19.1%	18.0	17.6	15.1
Downlink CCI	1.2%	1.4%	1.2%	27.0	26.6	27.0
Downlink ASI	2.0%	2.2%	2.0%	25.0	24.6	25.0
Total Noise	**90.9%**	**99.8%**	**100.0%**	**8.4**	**8.0**	**8.0**

TS Cork IB

*If the carrier does not close in clear weather, please disregard the rain up and rain down computations as they are likely to be incomplete

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