

UC San Diego



RVTEC 2023

HiSeasNet - US Academic Research Fleet Update

October 23, 2023

Thomas Lockwood, Info Systems Analyst III, Shipboard Technical Support, Scripps Institution of Oceanography

Extra Special Thanks

- NSF and ONR have supported our vision for reliable, resilient, always-on, high performance Internet service as an enabler of research and ship operations for years. Support during the COVID-19 pandemic was critical to the growth and success of our project, and for improving conditions on vessels
- Since 2022, ONR and NSF have funded a project to demonstrate the productivity that can occur with constant broadband bandwidth capability on deep-ocean research vessels



HiSeasNet Background

HiSeasNet is a project that provides Internet support to US-based oceanographic research vessels. We support coastal, regional, intermediate ocean class, global class and icebreaking vessels

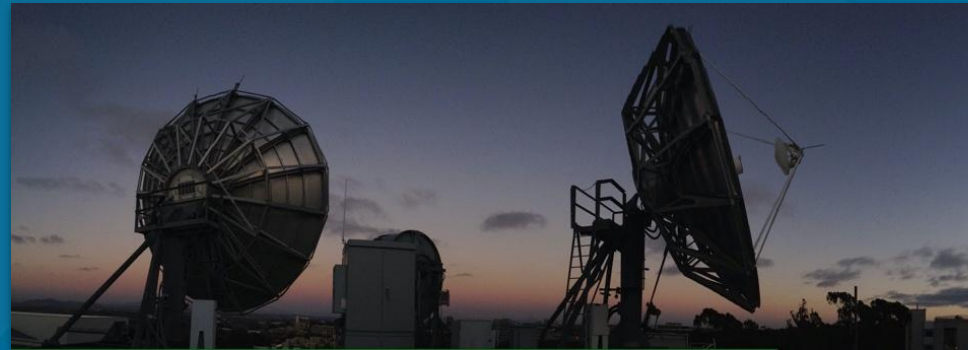


We are passionate about high-performance, high-availability networking to remote environments, leveraging economies of scale

"Any ocean, any time, anywhere"

HiSeasNet Background

1. Originally established as a satellite communications network in 2002, designed specifically to provide continuous Internet connectivity for US Academic Research Fleet (ARF) vessels
2. Based at UC San Diego; funding from NSF and US Navy ONR
3. Ground station located at the San Diego Supercomputer Center
4. Location well-situated to shoot effectively at satellites covering Atlantic and Pacific oceans
5. Two 7 m IEEE C-band dishes
6. One 2.4 m IEEE Ku-band dish
7. <https://hiseasnet.ucsd.edu/>



HiSeasNet Background

1. In addition to operating the ground station HiSeasNet also works with operators, mostly within the US Academic Research Fleet (ARF) to install and maintain above-decks equipment (ADE) such as radomes, and below-decks equipment (BDU), such as ACUs and modems
2. Since 2020, HiSeasNet has shifted focus from managing ground stations to managing contracts via several commercial service offerings
 1. Transitioned from boutique ground station to Marlink Sealink Services
 2. Inmarsat Fleet Xpress service added to HiSeasNet offerings
 3. As of 2023, pilot testing Iridium CERTUS installations for both
 4. As of 2022, funded to pilot test Starlink for the entire ARF
 5. Services based out of our San Diego ground station were discontinued in 2021, will be fully removed in 2023
3. Currently we serve 17 vessels within the ARF as well 2 vessels in the United States Antarctic Program (USAP)
4. Partner Projects:
 1. Ocean Exploration Trust
 2. RCRV during construction phase (pre-ARF)



Current State of fleet antennae

Current State of fleet antennae

1. Better living through leasing (2020-present)
2. 60 mo leasing model works well for annual budgets as the costs are amortized over 5 budget cycles
3. Leasing helps equipment lifecycles stay consistent – lease offerings are up to 60 mos with ~1 years extension possible
4. 60 mo lease with annual budgets is only possible due to the vendor accepting the risk



Current State of fleet antennae

1. 2 multi-system systems are in use
 1. Sealink Plus (bigger ships), a combination of Sealink and (out-of-band) Iridium CERTUS
 2. Fleet Xpress (all ships), a combination of Global Xpress and FleetBroadband
2. Each system has a high-performance component
 1. Sealink (C/Ku-band)
 2. Global Xpress (Ka-band)
3. Bigger dome traditionally = ~ more performance



C/Ku-band (Sealink) radomes

1. ~4 models in fleet
 1. Intellian v240M (2.4m C/Ku-band)
 1. Gen 1 2020-2021
 2. Gen 2 2021-present
 2. Cobham 9711 (2.4m C/Ku-band), <=2015-2018, Neil Armstrong & Sally Ride
 3. Intellian v150NX (1.5m Ku-band), 2022
 4. Cobham 6012 (1.5m Ku-band), Endeavor
2. 2.4m radomes on Global/Ocean Class
3. 2 vessels in ARF have Ku-only 1.5m
4. RCRV will also have dual Ku-only 1.5m
5. The "Gen 2" v240M has Mid & Low Earth Orbit (MEO/LEO) capability, two (or more) required.



Ka-band (Global Xpress) radomes

1. 3 models in fleet
 1. Cobham Sailor 100 GX (≤ 2019)
 2. Intellian GX100 HP (2020)
 3. Intellian GX100NX HP (2021-present)
2. The "NX" series of radomes has Low Earth Orbit (LEO) capability (Ka or Ku)
3. LEO function requires 2+ radomes, since two distinct satellites often need to be tracked at the same time



Pilot: L-band (Iridium CERTUS) antenna

1. 3 models in fleet
 1. Cobham Sailor 4300 (Sealink Out of and Access)
 2. Intellian C700
 3. Intellian C700 (Winterized Version)
2. Winterized models are being used to satisfy polar code communications requirements



Antenna installation standards

- Equipment installations focus on high-availability and high-reliability in terms of being online
 - Individual systems' target goal of 99% uptime capable
 - Compounded effect of multiple systems could result in near-continuous Internet uptime
 - Annually serviced
- **Geostationary/traditional (GEO)**
 - Sealink C/Ku-band (1.5m to 2.4m, 1-2 domes)
 - Rates at 4x4 Mbps to 20x20Mbps
 - Out-of-band Cobham 4300 for Sealink rescue from Marlink NOC
 - Global Xpress (Fleet Xpress Ka-band, 1-2 domes)
 - Rates at 2x2Mbps
 - FleetBroadband for backup
- **Low Earth Orbit (LEO)**
 - LEO systems may only need a single antenna since they look at multiple points in the sky
 - Iridium CERTUS for emergencies, polar code (not high throughput – ~0.5Mbps)
 - Starlink -- speeds in the range of 60-250Mbps (downlink), 6-30Mbps (uplink)
 - Pilot funded for 2022-2023 - "In Port/near shore" cellular alternative, at minimum
 - July 2023 Rachel Carson, Armstrong, Thompson and others coming
 - At-sea data rates may have notable bottlenecks
 - Each system has a monthly quota

Installation/airtime activity in 2021

- High-performance radomes installed or relocated: 17
 - Second only to 2020 for most radomes installed
- Expansion requests fulfilled: over 30
 - In June 2021, HiSeasNet had fulfilled the most bandwidth requests since the project's beginnings in 2002
 - "Normal" expansions have previously been on the order < 10 per year
 - Commercial service and scale has allowed this (but there are downsides)

Installation/airtime activity in 2022

Major radome overhauls on the decline

- Over 80% of the fleet overhauled during 2020-2021 and we are on a 5-6 year lifespan countdown for most ships
- Some ships have complicated schedules or installs that will take more time

NSF Baseline Bandwidth Increase fleet-wide for ARF in 2022

- Increase to Baseline Rates to satisfy Zoom minimum requirements
- Sealink 2.4m: 4x2 Mbps CIR up to 8x4 Mbps MIR
- FX: 2x2 Mbps CIR up to 8x4 Mbps MIR
- Highest feasible long term worldwide rates for current systems in use

ONR/NSF funding for additional Bandwidth beginning August 2022

- Sealink 2.4m: 8x8 Mbps CIR 10x10 MIR up to 20x20 CIR
- Only applies to select ships due to the nature of the funding

Installation/airtime activity in 2023

Additional Bandwidth funding via ONR, NSF

- ONR/NSF broadband experiment will continue beyond October 2023, into ~2025
- Funding has been renewed and augmented by Congress to continue this with FY2023 funds. Proposal being submitted to ONR this summer

5-ship emergency “pooled use” Iridium CERTUS

- Continued deployment of Intellian C-700 (some Winterized) CERTUS Terminals

Starlink pilot funded for all ARF vessels 2022/23

- SpaceX announced commercial “Maritime service” July 2022
- Revelle pilot Sep-Nov 2022 with actuated High Performance Starlink Business Terminal “roaming”, Best Effort Service
- After extended contractual negotiations as of June 2023 UCSD can now issue Purchase Orders
- First shipments happened over the summer. Remaining equipment orders in process.



Observed broadband benefits

1. Network stability (versus expansion model)
2. Concurrent Zoom sessions possible, allowing ops and science to consult experts concurrently
3. More possible to ship data from ship to shore in real-time or near-real time
4. Less planning needed for science support logistics
5. Possible to consider use of modern IT tools which depend on cloud
6. Ship's Crew increasingly able to leverage 21st century workflow solutions EG charts, parts shopping, HR, time reporting – many tools that have "gone digital"



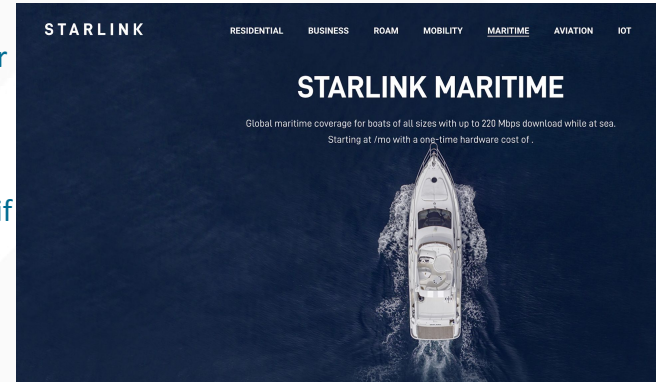
Starlink Maritime

What are the limitations of Starlink Maritime?

Best Effort Service: Starlink prioritizes network resources for Starlink Maritime users at sea and on terrestrial waters. Starlink Maritime service is provided on a best effort basis; stated speeds and uninterrupted use of services are not guaranteed. Starlink is not intended or registered for use as a Safety of Life at Sea (SOLAS) service at this time. In 2023, Starlink changed their offerings to only include quota-by-the-month airtime plans.

Coastal Waters: Starlink for Maritime should only be used in territorial waters where licensing is either held by SpaceX or the end user. Starlink Maritime is currently approved for use in the US. Many other countries are pending regulatory approval for coverage.

FCC Authorization Notice: Federal Communication Commission authorization to Starlink for in-motion services in the United States has been granted on a non-interference protected basis, i.e., unprotected basis with respect to operations in the 12.2-12.7 GHz band. Therefore, Starlink's in-motion operations, including for vessels, must accept any interference received from both current and future services authorized in the band – even if such interference causes undesirable operations for Starlink Services and its customers. Starlink in-motion Services must not cause harmful interference to any authorized service in the band, whether licensed or not.



Starlink in ARF

HiSeasNet is funded to install Starlink within ARF

- Fleet-wide Pilot; anticipated to be a near-shore high speed alternative to traditional GEO
- Expected speeds in ranges from 60-250Mbps (downlink) and 10-30 Mbps (uplink)
 - Multiple tiers within the network can affect actual speeds achieved.
 - No CIR, Original Commercial Maritime offering at lowest tier of access.
- Starlink network systems have recently added 50GB, 1TB or 5TB/mo usage quotas
- No long-term contracts or terms; SpaceX can change usage terms every month
- <https://www.starlink.com/map> for current live coverage map
- <https://satellitemap.space/?constellation=starlink> is also useful

Starlink in ARF





Revelle's initial Starlink experience

- Business Terminal with Mobile Priority Access
 - Same terminal used for Commercial Maritime offering
 - Higher access tier than commercial Maritime offering
- November 2022 – February 2023
 - Schedule: Alameda San Diego Papeete Punta Arenas Cape Town
 - Only had coverage offshore US/Mexico and Chile
 - Terminal dead prior to arrival in Punta Arenas.



Starlink In-Motion

Per <https://api.starlink.com/public-files/Starlink%20Service%20Plans.pdf>

STARLINK		SERVICE PLANS	
ONE LOCATION		ON THE GO	
 STANDARD Best for households	 PRIORITY Best for businesses and high demand users	 MOBILE Best for RVs, nomads, and campers	 MOBILE PRIORITY Best for maritime, emergency response, and mobile businesses
KEY FEATURES <ul style="list-style-type: none">UNLIMITED HIGH-SPEED, LOW-LATENCY INTERNET¹	KEY FEATURES <ul style="list-style-type: none">UNLIMITED STANDARD DATANETWORK PRIORITY²PRIORITY SUPPORTPUBLIC IP	KEY FEATURES <ul style="list-style-type: none">UNLIMITED MOBILE DATA ON LAND¹PORTABILITYPAUSE SERVICE	KEY FEATURES <ul style="list-style-type: none">ALL THE FEATURES OF GLOBAL MOBILE SERVICEIN-MOTION + OCEAN USE³NETWORK PRIORITY²PRIORITY SUPPORT



Flat High Performance Starlink Terminal



20.1 x 22.7 in panel in-motion use applications

Electronic Phased Array Ku-Band Antenna

Starshield in ARF

HiSeasNet is deploying Starshield within ARF

- In Dec 2022, SpaceX unveiled 'Starshield,' a military variation of Starlink. Details at <https://www.spacex.com/starshield/>. Terminals use Starlink service today with ability to use either Starlink or US Government owned constellation once deployed.
- Deployments of first phase of Flat Panel Starshield Antennas began in June 2023
 - Rachel Carson
 - Sproul
 - Sally Ride
 - Sikuliaq (2)
 - Thompson (2)
 - Neil Armstrong
 - Revelle / Langseth
- SpaceX has introduced resellers and is eliminating all Government direct sales. HSN ordering antennas for remainder of ARF and will migrate service to a reseller prior to June 2024.



Future: 2024 and beyond

1. Continue to observe and report on benefits of broadband Internet to research vessels
2. Leased equipment projects will continue for Ocean class and bigger. Cycling hardware at ~5 years is in the plans for all ships
3. Iridium CERTUS pilot will continue and be evaluated. Voice and L-band backup for Starlink on smaller vessels as FX usage fades.
4. Starlink pilot will continue and be evaluated
5. We are aiming to test other LEO/MEO systems coming to market in 2024 and beyond



Other LEO systems on the horizon

OneWeb

- Expected CIR speeds upto 195Mbps (downlink) and 37 Mbps (uplink)
- 634 OneWeb operational satellites now in orbit, constellation is complete and fully operational down to 35 degrees latitude.
- In Sep 2023, Intellian and OneWeb introduced an active electronically scanned array (AESA) panel solution for OneWeb (replacing dual stabilized dome solution)
- Original HSN plan was to retrofit dual Intellian GX100NX domes with Ku BUCs once certified for OneWeb use but the new phased array antenna solution would be simpler.
- Deep sea connectivity (south Pacific) will be a challenge till intersatellite links are introduced



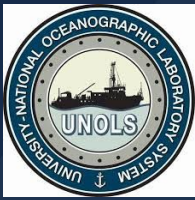
Other MEO/LEO systems on the horizon

Amazon Kuiper

- Expected speeds in the gigabyte range
- 2 operational satellites now in orbit, full constellation will consist of over 3,200 satellites.
- End of 2024 initial land-based services expected; unclear if at sea usage is a target market.
- Must deploy 1/2 their constellation by July 2026 *to maintain existing FCC License.*

O3b mPOWER

- Expected speeds in the multi-gigabyte range
- 4 operational satellites now in orbit, full constellation will consist of over 32 satellites.
- High-bandwidth connectivity between latitudes 50° N and 50° S expected



UC San Diego



Thank You! Questions?

hiseasnet@ucsd.edu