Ship/Shore Communications Subcommittee Findings and Recommendations

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The RVTEC Ship/Shore Communications Subcommittee

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Findings and Recommendations

Introduction

In 2002, the HiSeasNet (HSN) program started providing the Academic Research Fleet with near-constant computer network connectivity between the research vessels and shore. Since that time, the growth of high-bandwidth Internet has proliferated to the point where it is now considered essential in virtually all aspects of our lives. While the HSN infrastructure has expanded since then, in its current configuration, it has become inadequate in terms of bandwidth and robustness. On vessels where efforts are continuously made to provide and maintain state-of-the-art instrumentation, the lack of ability for the vessels to engage in viable ship/shore communications is a shortcoming. The single biggest complaint in the Fleet's Post Cruise Assessments (PCAs) is the inadequate ship/shore communications system. On top of the need for increased day-to-day bandwidth, telepresence, which requires even more bandwidth, is gaining momentum within the Fleet. It is clear that in this climate of rapidly changing technology and amidst continued requests for more bandwidth, the status quo is inadequate. The way science is conducted at sea has evolved and the vessel's basic support infrastructure must adjust accordingly.

To address this issue, the Ship/Shore Communications Subcommittee was formed. The funding agencies have been inundated with different ideas on what the path forward should be. This subcommittee was tasked to evaluate the various options and help the funding agencies develop a viable plan for bringing the US Academic Fleet's ship/shore communications into the modern age.

Background/Current Systems

HiSeasNet (HSN), operated out of Scripps Institution of Oceanography (SIO), purchases bandwidth on several satellites directly from the satellite operators. Utilizing an earth station at SIO, HSN becomes the ISP (Internet Service Provider) for most of the ships in the Fleet. The type of coverage (C-band or Ku-band) is dependent on the size of the ship and its general working area. It is a fixed rate, limited only by the available bandwidth. For C-band ships, HSN delivers 512Kbps (shared) to all ships from shore to ship and 96Kbps from ship to shore from each ship. The shore to ship bandwidth quota is shared with up to 5 ships on the same satellite beam which can, and often does, decrease the bandwidth to 96Kbps/ship. Ships using Ku-band see a similar setup with shore to ship bandwidths of either 192kbps (shared among up to 3 ships) or 256kbps (shared among 4 ships) and 64Kbps connections back to shore from each ship. The maximum capacities of the current HSN infrastructure is as follows:

	Shore to Ship	Ship to Shore
C-band	2Mbps	2Mbps
Ku-Band	1.1-1.6Mbps	900Kbps-2Mbps

In 2013 4.8 TB was pushed through the HSN on all beams in all directions.

After several years of HSN service, it became clear that an independent back-up system for HSN was required to provide 24/7 Internet connection for the Academic Research Fleet. Ships worked outside of the HSN footprint, antennas were unavoidably shadowed by superstructure on certain headings and as the complicated antennas aged, they experienced failures that could not always be remedied at sea. So in 2009, NSF funded a proposal to use **INMARSAT Fleet Broadband (FBB)** as the system to backup HSN. Unlike HSN, FBB is a plan billed by the megabyte (MB) through a contract with WorldLink. The current FBB contract allows bandwidth to be pooled so it can be moved and allocated to various platforms as needed. Woods Hole Oceanographic Institution (WHOI) actively manages this pool. Not all of the ships in the Fleet have HSN but all have FBB. The Academic Fleet pays for approximately 1.2 TB/year. For a list of the ships within the Academic Research Fleet and the communications systems with which they are equipped, see Appendix A.

There are pros and cons for each system in their current form. With HSN, C-band has global coverage and both C-band and Ku-band allow for the passage of relatively high amounts of data at a low cost. The problems, however, include

- Insufficient bandwidth to handle the needs of the ships causing a very slow user experience, often unusable for some activities.
- The C-band antennas are large and, due to their size, complexity and their location on the ship, have higher maintenance costs (to include both spare parts and personnel time).
- Existing hardware is outdated on many vessels.
- The current shipboard and earth station hardware are not capable of efficiently handling increased bandwidth.
- The current HSN earth station has limited C-band and Ku-band footprints and ships often leave these footprints (esp. Ku-band). Special arrangements can be made for ships traveling outside of the footprint (e.g. working in the Indian Ocean Region) but these are often costly due to their short term nature.

FBB uses the L-band spectrum and like C-band, is global in coverage. It utilizes a smaller, very robust antenna. The antennas are relatively inexpensive and the maintenance costs are low. The negotiated service plan of an annual pool of shared minutes creates a lot of flexibility on who can use how much data and when. Issues with FBB include

- Its limited capacity. The current maximum bandwidth is 432 Kbps. This decreases depending on how many other vessels are in the area. This is at times better than HSN but it is still lacking.
- The system is not capable of handling Level 2 telepresence (see below).
- The cost. Although WHOI has negotiated a very good deal per MB, it is still much more costly than the same amount of data being pushed through HSN.

Future day to day requirements

The Ship/Shore Communications Subcommittee convened for the first time on 20 November 2013, at the annual RVTEC meeting in College Station, Texas. The Subcommittee developed a list of nominal bandwidth requirements for day-to-day operations under normal conditions for the next three to five years. The list of the requirements for the various tasks can be found in Appendix B. Upon analyzing this list and the minimum reasonable requirements for each (assuming that all of the operations would not be happening simultaneously), the Subcommittee estimated that 512 Kbps shore to ship/256 Kbps ship to shore for each C-band ship and 256 Kbps shore to ship/256 Kbps ship to shore for each Ku-band ship should be sufficient to minimally satisfy these requirements. This is four times the current shore-to-ship HSN capacity.

Telepresence requirements

With the evolution of the technology around ship/shore communications, and the desire for more community outreach, the requests for telepresence in its various forms have increased dramatically. Telepresence can vary from streaming low bitrate standard definition video from ship to a passive audience on the Internet to full-blown telepresence-enabled science with scientists located at a shore-based facility like the University of Rhode Island's (URI) Inner Space Center, viewing multiple high-bitrate high definition video streams, using push-button intercom voice communications and large file transfers that enable shore based scientists to actively participate in the day-to-day cruise decisions. The different models of telepresence can be broken down below. Please note that these bandwidth requirements are in addition to day-to-day bandwidth requirements.

Level	Type	Bandwidth		Example
		Ship to Shore	Shore to Ship	
1	Public Viewing	1.5-2Mbps	512Kbps	Streaming standard definition video to the internet.
2	Remote Learning/ Media Events/ Outreach	1.5-2Mbps	1024Kbps	Streaming standard definition video to the internet with direct interaction (2-way audio/video) with a school, other venue or media via two-way audio.
3	Telepresence-Enabled Science	6.0-20Mbps	1.5Mbps	Streaming at least one channel of high definition video to shore with bi-lateral audio support to shore based scientists working daily with ship-based scientists on a cruise.

The Fleet has already participated in various telepresence events. With the purchase of additional bandwidth, Principle Investigators (PIs) successfully streamed standard definition video through a C-band HSN system. Using additional bandwidth, a third party earth station, and a different satellite, high-definition video has been streamed from the THOMPSON using their upgraded dual C/Ku-band system and also on the ATLANTIS with the use of URI's mobile C-band telepresence van. Requests for each of type of telepresence has increased significantly. This trend is likely to continue as the technology becomes more available. The upgrades to the HSN infrastructure proposed in this report will be sufficient to allow for the support of Level 2 telepresence in the Fleet given the purchase of additional bandwidth.

Bandwidth Management

There is great concern that in a short time a 'bigger pipe' will be similarly clogged if the newly increased bandwidth is not actively managed. Currently there is no fleet-wide Bandwidth Management Plan. Ships use different mechanisms within their means to manage use and mitigate abuse. This can range from high-tech systems that monitor IP addresses and shut down large bandwidth users and/or ban certain websites, to low-tech solutions such as only allowing one public computer to be connected to the Internet. Although these systems generally keep the Fleet links in congested but usable states, inconsistencies across the Fleet result in inefficient use and variable user experiences between ships and cruises.

The committee discussed different options for bandwidth management and quickly discovered that this is not as simple as saying everyone gets X amount of bandwidth or no one can go to sites A, B and C. Ships have different systems capable of different throughput at different costs. HSN and cellular technology are use-it-or-lose-it whereas with FBB you pay for what you use. In addition, the Fleet has a variety of networks, different in-house technical expertise, and operational models (e.g. long cruises vs. short). With all this, the Subcommittee decided that is best to collect usage data for the first year to address questions such as:

- Do some users use a lot more bandwidth than others? Who are those users?
- Is there a steady-state amount of use on a particular satellite? (i.e. when some ships are busy, some are not).
- Can users on an individual cruise be put in some sort of common bandwidth-use category with any success?
- Are vast abuses of bandwidth obvious?
- How much behavior change is there when per-user usage (volume only) is made public in real-time or on a regular basis?
- Is the usage pattern at the beginning of a cruise different than the end?
- Do certain websites lend to overuse (e.g. Youtube)?

It is doubtful that a “one size fits all” policy can be imposed. There are too many differences between the ships, their systems, users, and mission requirements. That said, once aggregate statistics are collected and analyzed, the Subcommittee feels that they will have the means to create a more intelligent policy and enforcement protocol that is flexible enough to cover the different use-cases while limiting abuse and providing a better user experience across the Fleet.

Upcoming Technology

C-band, Ku-band and L-band are still widely used within the maritime industry. Satellite providers are investing in new equipment and improving the overall user experience with items like smarter, more efficient modems that will allow for better use of bandwidth and multi-band antennas that will enhance the flexibility of the systems.

In the next few years, a large, new spectrum, Ka-Band will be coming into the mobile maritime arena. This new bandwidth spectrum looks to be very promising as the large spectrum gives the potential for high-capacity throughput and the antennas are relatively small compared to C-band (1.0m v. 2.4m). The potential issues with Ka-band are the limited footprint, the potential for rain fade issue due to its higher frequency band, 3^{rd} party service policies, and cost.

INMARSAT is coming out with a new product called Global Xpress (GX). INMARSAT anticipates that GX will provide nearly global coverage with Ka-band (very high bandwidth) when available and will revert to L-band (FBB) when it is not. Coverage will depend on which spot beams are available in a given area at a given time. The antennas will be approximately the size of the Ku-band antennas making installations possible on smaller vessels. The details about dependability and cost are yet to be determined but the arrival of Ka-band in the near future is something to watch. The Indian Ocean GX coverage will be available in Q2 2014 and the global coverage is estimated to be fully operational by Q2 2015.

Recommendations

Based on our review of the ships current systems, the immediate and projected connectivity needs of science and operations at sea and our understanding of the current and projected technology, the Subcommittee recommends a three-year modernization plan. Initially, the Fleet should continue with the current system of using HSN (C-band and Ku-band) as the primary source for connectivity with FBB as a robust back-up. However, the Subcommittee strongly recommends that the HSN bandwidth be increased and the supporting equipment upgraded to increase efficiency and ultimate capacity, with the ultimate goal towards support of Level 3 telepresence. Additionally, INMARSAT GX (L/Ka-band) should be comprehensively tested and evaluated once it is available.

Year 1 (2014):

- Keep HSN as the primary system and increase bandwidth by 4x:
  - C-band per ship: 512Kbps shore to ship/256 ship to shore.
  - Ku-band per ship: 256Kbps shore to ship/256 ship to shore.
- Replace the outdated HSN modems (shipboard and earth station) with newer, more efficient modems that can accommodate the proposed increased day-to-day bandwidth requirements as well as telepresence-enabled science (Level 3). This capital investment will pay for itself within the first three years of use with more efficient use of bandwidth creating savings over the long run.
- Keep the FBB as the back-up system with the current quotas.
- Begin testing of INMARSAT GX testing in the Indian Ocean if ship scheduling permits.
- Begin a bandwidth-monitoring program to set the groundwork for a fleet-wide Bandwidth Management Plan. The program should supervised by HSN with input from the Subcommittee.

- The HSN group should work with operators to identify problem equipment and proactively make updates.
- Develop guidance plan for both scientists and operators/technicians to manage and support telepresence requests. This plan would include how to request telepresence support, requirements to meet the different levels of support (e.g. shipboard equipment, shipboard and shore-side personnel, bandwidth, shore-side facilities) and implementation.
- Develop a plan for shore-side infrastructure improvements to regularly support Level 3 telepresence through the HSN earth station.

Year 2 (2015):

- The Subcommittee will meet at the 2014 RVTEC/INMARTECH Meeting at Oregon State University (OSU) in November to review Year 1 and specifically to evaluate the bandwidth usage data. The Subcommittee will make recommendations for the implementation of a Bandwidth Management Plan.
- Continue with the HSN Year 1 bandwidth allocation.
- Review FBB usage and re-negotiate INMARSAT source of satellite communications to include the needs of the community including all ship classes and OOI.
- Continue testing of the INMARSAT GX system. Testing should include day-to-day activities as well as streaming high-definition video and should be conducted on different ships and in different parts of the world.
- Refine the telepresence guidance plan as necessary.

Year 3 (2016):

- Continue GX testing as required and evaluate system for use within the Fleet.
- Continue with the HSN Year 1 bandwidth allocation.
- Continue with FBB as a back-up system.
- Review bandwidth usage and the success of the Bandwidth Management Plan. Modify as required.
- At year's end, re-evaluate the fleet's ship/shore communications model (HSN primary/FBB back-up) with an eye on the new technology (especially GX). Create new recommendations as necessary.

General:

- All new ships should be brought on line with hardware capable of handling telepresence-enabled Science (at least 6Mbps).
- Upgrade existing ships' HSN amplifiers to become capable of handling telepresence-enabled science as need and funding dictate. It is recommended that the ATLANTIS be one of the first to receive upgraded equipment as she is the host ship for the Alvin which is expected to be used more often for telepresence.
- HSN should look into 3-year contracts for bandwidth procurement. It is hoped that longer term contracts could provide cost savings.
- Investigate the availability of earth stations operated by academic/non-profit institutions that can see areas that the HSN earth station cannot (especially IOR). These earth stations may be more cost efficient and flexible than commercial providers currently used.

The Subcommittee recognizes that the costs of the modernization plan will not be trivial and funding could be an issue but feels this plan will most cost effectively bring the ship/shore communications into the modern age.

Appendix A - Requirements

Ship/Shore Communications Connectivity Requirements

- Internet at sea
    - Science Operational Support
    - Ship Operational Support
    - Data to ship
    - Data from ship
    - Ship based email
    - Shore based/web email
    - Morale
    - Non-cruise related science business
- Telemedicine
- Voice
    - Science Operational
    - Ship Operational
    - Safety
    - Morale
- Video-streaming
- Video-conferencing
- Desktop-sharing (e.g. Webex, GoTo meeting)
- Telepresence
- Virtual Private Networking (VPN)
- Two independent systems for redundancy
- Auditing capabilities
- Security
- Flexibility
- Scalability
- Reliability

Total Expected Bandwidth Requirements (3-5years)

C-Band (per ship): 512Kbps shore to ship/ 256Kbps ship to shore
Ku-Band (per ship): 256Kbps shore to ship/ 256Kbps ship to shore

Appendix B – Systems

U.S. Academic Research Fleet Ship/Shore Communications per ship

Ship Name	Institution	Class	HSN	FBB
R/V *Melville*	Scripps Institution of Oceanography	Global	C-band	x2
R/V *Revelle*	Scripps Institution of Oceanography	Global	C-band	x2
R/V *Knorr*	Woods Hole Oceanographic Institution	Global	C-band	x2
R/V *Thompson*	University of Washington	Global	C-band*	x1
R/V *Atlantis*	Woods Hole Oceanographic Institution	Global	C-band	x2
R/V *Sikuliaq*	University of Alaska-Fairbanks	Global	C-band	x1
R/V *Langseth*	Lamont-Doherty Earth Observatory	Global	C-band	x2
R/V *Kilo Moana*	University of Hawaii	Ocean/Int	C-band	x1
R/V *Oceanus*	Oregon State University	Ocean/Int	Ku-band	x1
R/V *Endeavor*	University of Rhode Island	Ocean/Int	Ku-band	x1
R/V *New Horizon*	Scripps Institute of Oceanography	Ocean/Int	Ku-band	x1
R/V *Atlantic Explorer*	Bermuda Institute of Ocean Sciences	Ocean/Int	Ku-band	x1
R/V *Point Sur*	Moss Landing Marine Lab	Regional	Ku-band	x1
R/V *Pelican*	Louisiana University Marine Consortium	Coastal/Local	Ku-band	x1
R/V *Walton Smith*	University of Miami	Coastal/Local	Ku-band	x1
R/V *Sproul*	Scripps Institute of Oceanograph	Coastal/Local	none	x1
R/V *Sharp*	University of Delaware	Regional	none	x1
R/V *Savannah*	Skidaway Institute of Oceanography	Coastal/Local	none	x1
R/V *Barnes*	University of Washington	Coastal/Local	none	x1
R/V *Blue Heron*	University of Minnesota-Duluth	Coastal/Local	none	x1

Appendix C – Subcommittee Members

RVTEC Ship/Shore Communications Subcommittee Members

	First Name	Last Name	Institution
1	Dwight	Coleman	URI Inner Space Center
2	Steve	Foley	SIO/HiSeasNet
3	David	Fisichella*	WHOI
4	Sarah	Kaye*	USCG/HEALY
5	David	O'Gorman	OSU
6	Webb	Pinner	Capable Solutions
7	Laura	Stolp	WHOI
8	Al	Suchy	WHOI
9	Woody	Sutherland	SIO
10	Scott	Walker	USAP/LM
11	Trevor	Young*	UH
12	Jim	Holik	NSF/OCE
13	Tim	Schnoor	ONR
14	Alice	Doyle	UNOLS

* Unable to attend 16January14 meeting