Introduction to Telepresence

Ocean environments are complicated combinations of many different geological, chemical, physical, and biological processes. Understanding those processes at a particular location requires many different kinds of experts. The problem is, those experts are often scattered all around the world, and even if it were possible to bring them all together, there isn't enough space aboard ships of exploration to carry every expert that might be needed. The solution to this problem is telepresence; a group of technologies that allows people who are thousands of miles away from an exploring ship to directly participate in exploration activities. In addition to providing access to a broad range of scientific expertise, telepresence also allows the public to observe and follow expeditions in real time.

The foundation for telepresence is radio technology, and while students may consider radio to be old and pretty much out-of-date it is the basis for cell phones, wireless Internet, satellite communications, garage door openers, remote controls, and many other things that we use every day, and that we think of as "modern." Aboard the NOAA Ship *Okeanos Explorer*, the most prominent piece of radio equipment is the large dome (radome) that houses the ship's 2.4-meter Very Small Aperture Terminal (VSAT) dish antenna, owned and operated by NOAA's partners at the Global Foundation for Ocean Exploration.

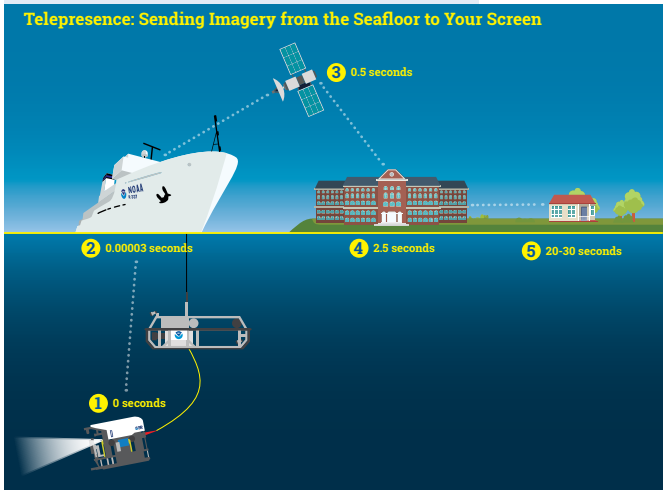
The VSAT antenna is the critical link between the *Okeanos Explorer* and the satellites that relay information to shore-based Exploration Command Centers (ECCs) where scientists are able to be directly involved with expedition operations. These satellites are 22,753.2 statute miles ("normal" miles, not nautical miles) above Earth's surface. At this altitude, the satellites are geosynchronous, which means their rotational speed matches the speed of Earth's rotation so they appear to remain in a fixed position when viewed from Earth's surface. On the ship, computers, motors, and other hardware make constant adjustments that compensate for the ship's heave, roll

The VSAT (large dome; stands for "Very Small Aperture Terminal") is the critical piece of infrastructure that makes telepresence possible. Image courtesy NOAA OER, Deepwater Wonders of Wake. *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1703/logs/mar16/welcome.html*

Telepresence technology allows anyone with Internet to follow an exploration...even over breakfast while on vacation. Image courtesy of NOAA *Okeanos Explorer* Program, Gulf of Mexico 2014 Expedition. *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1402/logs/apr18_b/media/tarttboys.html*

Scientist Scott France participates in the dives from his home office via telepresence. Image courtesy of NOAA OER, 2016 Deepwater Exploration of the Marianas. *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/logs/jun28/media/1605scott-france.html*

Telepresence explained graphically. Image courtesy NOAA OER.



The NOAA Ship *Okeanos Explorer*, America's ship for ocean exploration. Image courtesy NOAA. *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/logs/mar1/media/okeanos.html*

and pitch to keep the antenna pointed toward the appropriate communications satellite. Radio transmitters and receivers connected to the VSAT antenna operate on "C -band" frequencies, which are in the microwave region of the electromagnetic spectrum.

To bring experts in many remote locations onto the exploration team, the telepresence system must provide two-way communication for several types of information. Live video is perhaps most important, and is provided in three high-definition streams. The first is from the camera of the the remotely operated vehicle (ROV) *Deep Discoverer*; the second is from the camera sled *Serios* (for additional information about the two-body ROV system, please see the *Introduction to Underwarer Vehicles http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-URintro.pdf*); and the third video stream can carry video from the ROV's navigation computers display, the ROV's scanning sonar, information from the ROV's Conductivity, Temperature and Depth profiler (CTD), or one of the additional camera on the ROVs. These video streams operate in near-real time, but there is always a time lapse before a viewer on shore can see what happened on the bottom of the ocean (this lapse is called latency). With a specialized internet connection the latency is only about 2.5 seconds. With other types of connection latency can range from 5 to 30 seconds. The live video streams only move information one way. To move information from shore-based scientists back to the ship in real time, telepresence relies on a teleconference call system and an online chatroom. Like most chatrooms, anyone logged into the system can add their comments to the conversation.

Two-way telepresence communications also allows other kinds of participation. To annotate video recorded during ROV dives, for example, NOAA works with Ocean Network Canada to use their Oceans 2.0 software suite to allow researchers anywhere in

the world to make notations and observations that are publicly available. These annotations are a very important part of the process of working up video data for further analysis, as well as for helping manage and search all the data that are collected. Another example of participation via two-way telepresence communication is "telepresence mapping" in which key members of the expedition team work from the University of New Hampshire's ECC to run mapping operations on the ship, as well as do data processing tasks and even assist with troubleshooting sonar systems.

Telepresence streamlines other data management tasks with a custom suite of software and standard operating procedures that automatically collect raw and some processed data from all the different acquisition computers, and then move that data to a central server called the data warehouse. Then the system automatically moves all the data over the satellite connection to shore as bandwidth is available. Once the data are in the data warehouse, any member of the science team can access the data on an FTP site.

An Exploration Command Center (ECC) at Underwater World Guam. Image courtesy of the NOAA OER, 2016 Deepwater Exploration of the Marianas. *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/logs/apr20/media/uww1.html*

(Left) An RTS unit in *Okeanos Explorer*'s control room. RTS units use an IP-enabled intercom system, leveraging the *Okeanos Explorer*'s Internet connectivity to connect all of the ship-based and shore-based intercom units into a single system. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010. *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july09/media/rts_unit.html*

(Below) Prior to a cruise, NOAA OER coordinators conduct training webinars to teach scientists and students how to use Internet-based collaboration tools to participate in the expedition from shore. Here, a group tunes into the live feeds from the Inouye Regional Center (IRC) ECC in Hawaii. Image courtesy of the NOAA OER, 2016 Deepwater Exploration of the Marianas. *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/logs/apr20/media/irc.html*

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