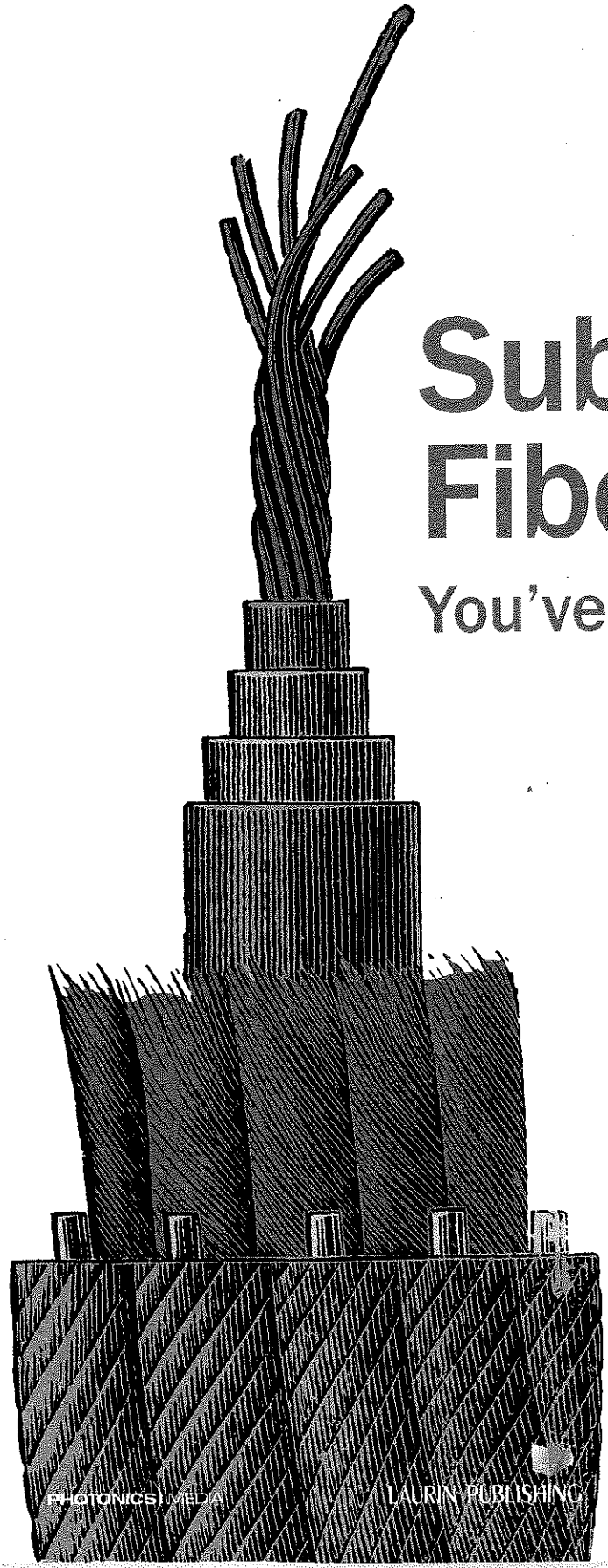
www.photonics.com

February 2019

PHOTONICS spectra



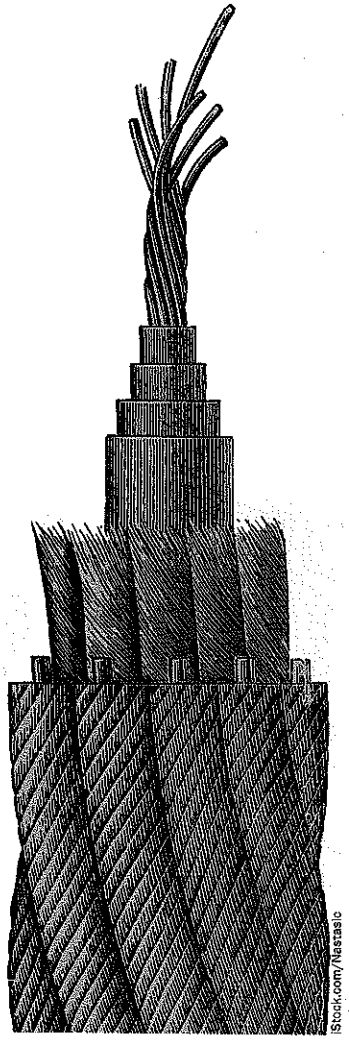
Subsea Fiber Optics

You've Come a Long Way

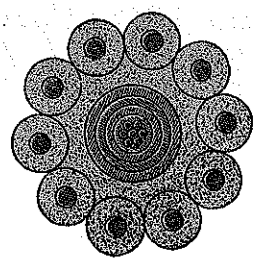
PHOTONICS MEDIA | LAURIN PUBLISHING

Data Needs Drive **Underwater Fiber Developments**

The data deluge, the majority of which is transmitted via subsea cables, is propelling innovations in a range of fiber optic components.



iStock.com/Nastasic



Drawing of first stable trans-Atlantic telegraph cable, laid 1865-66.

BY HANK HOGAN
CONTRIBUTING EDITOR

Data traffic will nearly double in the next three years, according to analysts. Many bits will travel between data centers over land, and many will make the long journey across the ocean, moving through fiber optic cables that sit on the seafloor.

An estimated 1.2 million km of submarine fiber is in use today. Government statistics indicate that nearly all international data traffic, perhaps as much as 99 percent, travels via submarine cable, with satellite transmissions making up the rest. Submarine fiber cables are more economical for moving data than satellites.

No matter where or how bits travel, an increasing number will pass through fiber in the next few years.

"The bandwidth growth is roughly 40 percent in all regions around the world, showing no signs of slowing down," said Brian Lavallée, senior director of portfolio management at networking systems, services, and software company Ciena of

Sensing with Submarine Fibers

Data- and telecommunications are just two uses for submarine fiber optics, which are also used for sensing temperature, sound, and strain during the monitoring of offshore wind farms and oil and gas fields. Such needs are prompting advancements in fiber and cable construction.

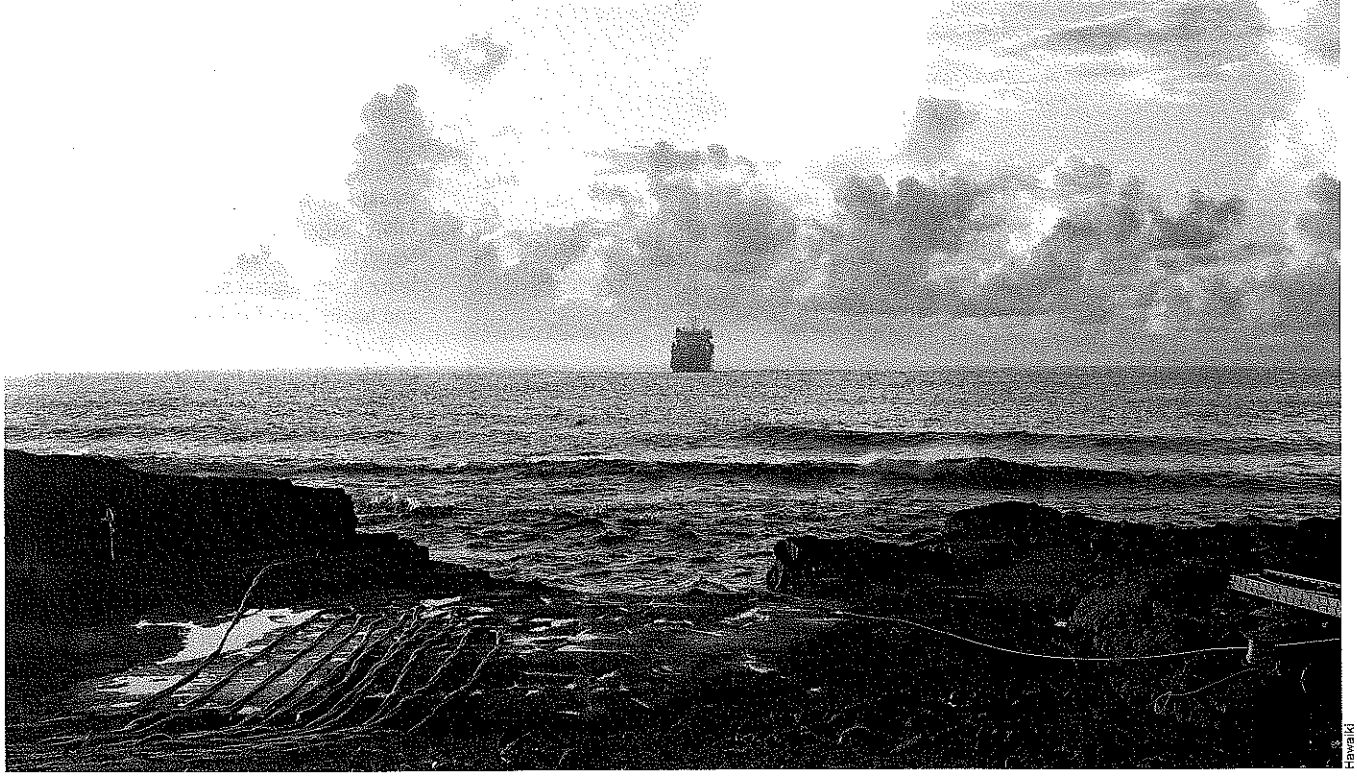
Cables used by offshore platforms do carry data. But typical distances run from a few tens of kilometers to as many as 100, said Dana Dutoit, industrial markets manager at cable maker AFL of Duncan, S.C. So, there's less of a need to achieve ultralow attenuation than with transoceanic cables, which can span thousands of kilometers in total.

Both types of cables, however, are affected by environment. "Hydrogen is a problem in subsea cables, especially when you're in warmer waters," Dutoit said.

The gas degrades the fiber's transmission of light and thereby reduces performance. Hydrogen can be released when microbes eat away at the plastics in the cable, or when water corrodes the metals. AFL minimizes hydrogen load by encasing its cables in hermetic stainless steel tubes, leaving the fiber more free to move about and thereby remain strain-free. If the fiber is located in a sensing application, where detecting strain is important, then the fiber is suitably coupled to the cable.

For any sensing use, an interrogating laser beam — which may have a wavelength of 1064 nm — travels down the fiber. The interaction of the light and the fiber changes due to environmental effects, so tracking these changes allows measurement of temperature, strain, and even sound. A leak may create a detectable vibration; therefore, the last can be important when monitoring an undersea pipeline.

Looking forward, Dutoit predicted a growing use of fiber in submarine communications, signaling, and sensing. "As we continue to make advancements in how we package fiber and how we can achieve long, continuous, splice-free lengths with low attenuation and good optical transmission properties," he said, "that'll continue to enable more and more utilization of fiber in subsea networks."

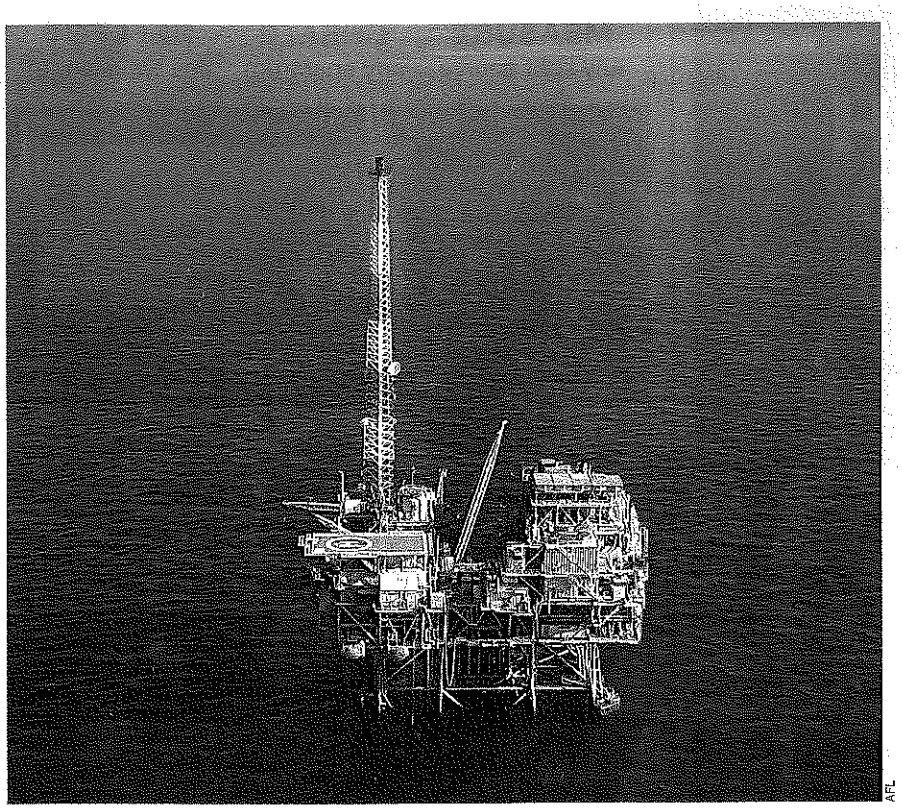


Hawaiki

A ship lays down a fiber optic cable. The cable will eventually span the Pacific and sit on the seafloor while carrying terabits of traffic.

Hanover, Md. The company makes the terrestrial and submarined modems that sit at the end of fiber, translating digital data into a stream of optical signals and vice versa.

A lot of traffic is initiated by people, in the form of videos watched on mobile devices, or games played on mobile or dedicated systems, for example. A growing portion, however, travels directly from machine to machine. "Data centers talk to each other, and they talk to each other a lot," Lavallée said.



AFL

Submarine fiber cables connect offshore wind farms and oil platforms to land. The fiber is used for communicating, signaling, and sensing.

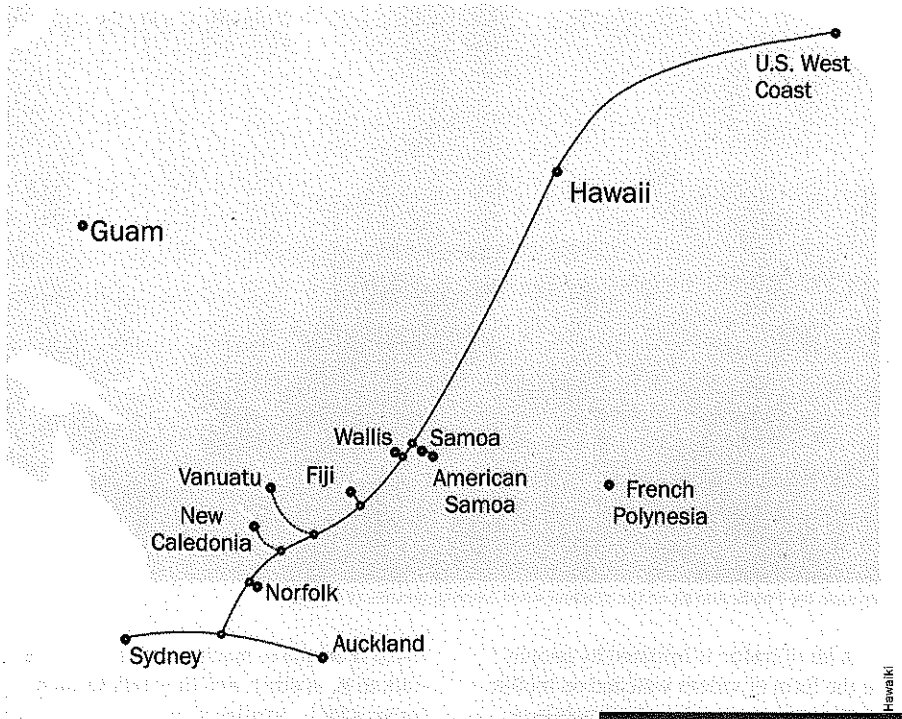
The fiber optic cables, the repeaters that sit on the ocean floor and boost the signal moving down the fiber, and the transceivers located at both ends of the cable all must deal with the deluge. Management of data demand is pushing fiber optic technology to its limits and forcing the industry to innovate when it comes to transceivers, wavelength bands, and the number of fibers per cable. The needs of other subsea applications are driving their own respective advancements. (See sidebar: "Sensing with Submarine Fibers.")

Linking Pacific islands

The impact of such data growth can be seen in the work of Hawaiki Submarine Cable LP of Auckland, New Zealand. The company operates a carrier-neutral, 15,000-km submarine cable that links Australia, New Zealand, Hawaii and Oregon in the U.S., and various islands of the Pacific.

This connectivity is intended, in part, to drive stronger economic and cultural ties between Pacific nations and the rest of the world, said Rémi Galasso, founder and CEO of Hawaiki. The company's cable will support improvements in distance education and remote health services, areas that Galasso said have traditionally been lacking in the Pacific.

"We're already seeing evidence of this



Route of a transoceanic cable across the Pacific.

transformation, in particular with Pacific Island organizations reaching out to counterparts in New Zealand and Australia to launch new digital services for schools and health care facilities," he said.

Hawaiki began commercial operations in July 2018. Due to strong demand, the company has already upgraded the transceivers and networking technology of its systems by contracting with Ciena. This has increased data transmission capacity from an initial 43 Tb/s to 67 Tb/s, with a potential for even faster speeds in the future.

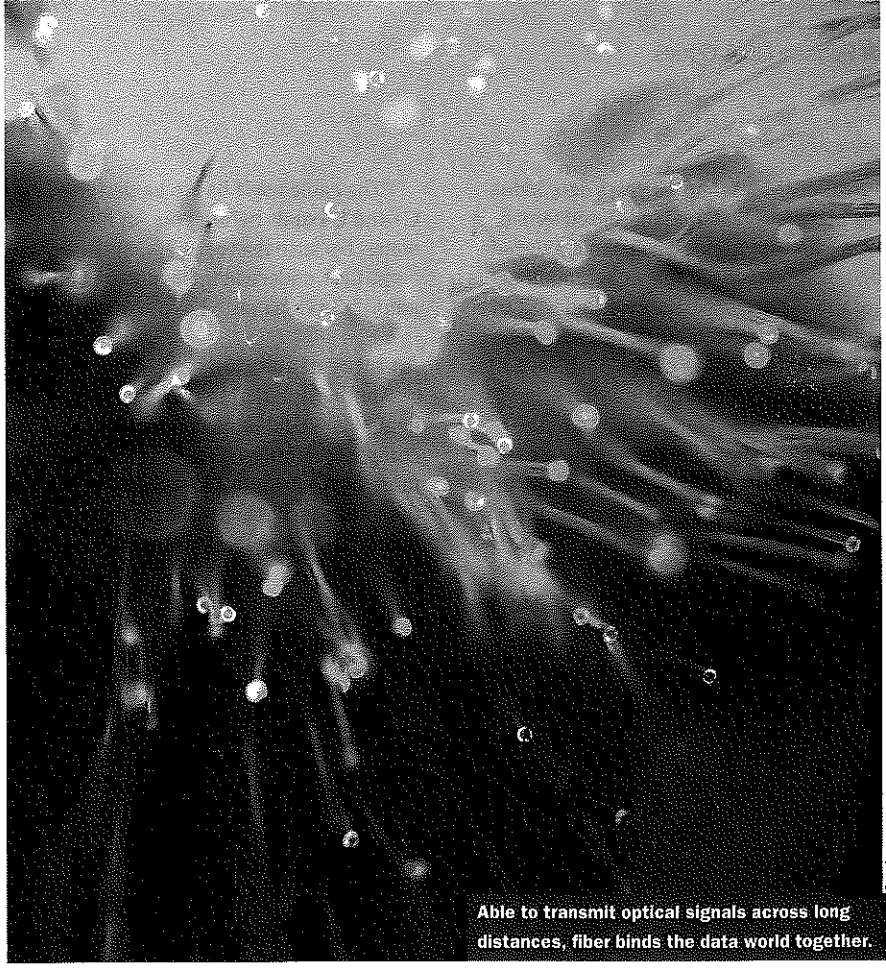
Looking forward, fiber technology is beginning to approach its transmission limits, Galasso said. There are ways around this, but any innovations must account for the lifetime of submarine cables, which are designed to last 25 years. When the cables are initially installed in the ocean, they are carefully laid and trenched to avoid contact with shipping

lanes and rough subsea terrain. Near the shore, they may be covered with rock for protection. This process, along with the expense of the cable, puts the costs of deploying a submarine cable at hundreds of millions of dollars, an investment that companies will not want to discard unless there is no other way to address rising data requirements and other needs.

Increasing capacity

Data capacity solutions include improving transceiver technology. Ever faster optoelectronics could allow the development and implementation of clever algorithms that would increase capacity by making it possible to cram more bits into the optical signal. Another advancement would involve expanding the range of the optical wavelengths used. Traditionally, single-mode submarine fiber uses the C-band, which runs from 1530 to 1565 nm. Next is the L-band, spanning 1560 to 1625 nm.

Putting lasers in the transceivers to utilize the extra spectral room of the L-band would help increase capacity. The technology to do this is not new, said Ciena's



Corning

Able to transmit optical signals across long distances, fiber binds the data world together.

Lavallée. More than 15 years ago, industry players rolled out land-based versions of L-band solutions. Then about a decade ago, testing showed that coherent modems for the L-band spectrum worked well over submarine cable, yielding improved results because subsea cables perform better than their terrestrial counterparts.

Adding a new band is not a simple matter of swapping out transceivers at the ends of the cable, however. There are many repeaters that must also meet the new requirements.

"The cable itself has to be designed for C- and L-bands before you put it in the water, because the repeaters, or the optical amplifiers underwater, have to be able to amplify both bands," Lavallée said.

An array of solutions

Another solution to rising data demands would be to choose a cable composed of more fiber pairs. Packing more fibers into a cable would increase the total data capacity because there would be more physical lanes through which optical traffic could travel. This could be accomplished by making the fibers narrower, by making the enclosing cable wider, or by using a combination of the two.

However, Sergejs Makovejs, market and technology development manager at fiber maker Corning Inc. of Corning, N.Y., said that having low attenuation, or little loss of optical signal per mile traveled, was critical for submarine fiber. Low attenuation increases the distance that can be traveled before a repeater is required, which then reduces the number of amplifying repeaters needed.

The light-carrying part of the fiber — the core — should thus remain large in diameter, with the precise measurement being discussed within the industry. At the same time, the diameter of the coated fiber would need to shrink, with the size decreasing from about 250 µm to perhaps 200 µm. This would allow for a significant increase in the number of fibers, leading to a boost in the total capacity of the cable. But again, this only works if the cable is properly configured before installation.

Attempts to increase the number of fibers per cable must also take environment into consideration. A submarine cable is subject to extreme pressure because it sits on the cold seafloor. Seawater can also be corrosive to the plastics and other materials in the cable. Earthquakes, underwater landslides, boat anchors, and seabed trawlers can all cut or damage cables. If such an incident happens, operators do not abandon the cable.

"If the cable is damaged, [it] needs to be retrieved from the bottom of the ocean, repaired, and then put back. This [need to be able to retrieve the cable] requires [it to have] great strength," Makovejs said.

Variations and combinations of all these solutions may be used, depending on their costs and how fast data capacity needs grow and fiber technology advances.

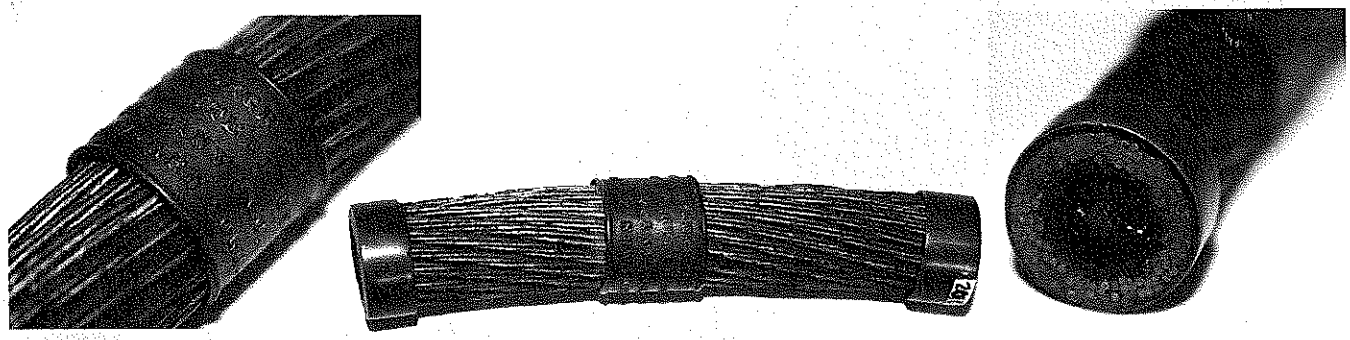
"There are at hand numerous solutions to continue to meet market demand at competitive costs," said Hawaiki's Galasso. "Choices will be made on the basis of cost per bit and redundancy requirements."

hank@hankhogan.com

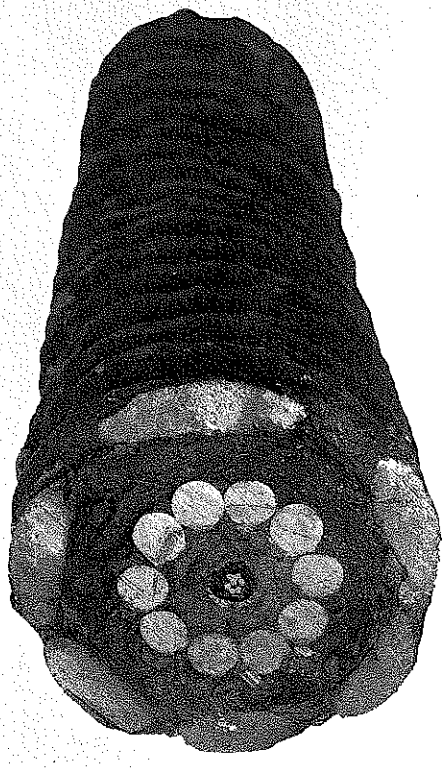
Government statistics indicate that nearly all international data traffic, perhaps as much as 99 percent, travels via submarine cable.

Ocean of Information

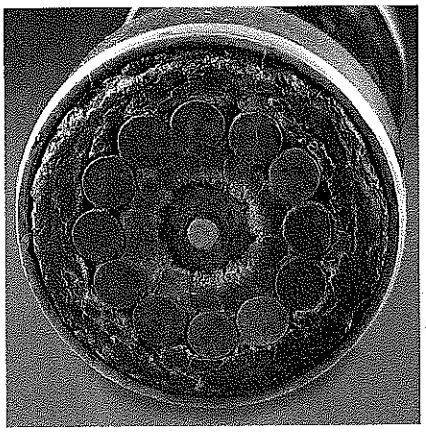
These fragments of early telegraph communication cables, precursors of what is now a mature fiber optics system, symbolize an insatiable human desire to connect. The first trans-Atlantic cables — which were laid in 1858 between Trinity Bay, Newfoundland, and Valencia, Ireland, and formally connected the United States with Great Britain — were cause for tremendous celebrations in New York and other cities. Telegraph cables were eventually replaced by telephone cables, which, in many cases, have since been replaced by fiber optics. Fiber optic cables carry more than 90 percent of all international data traffic.

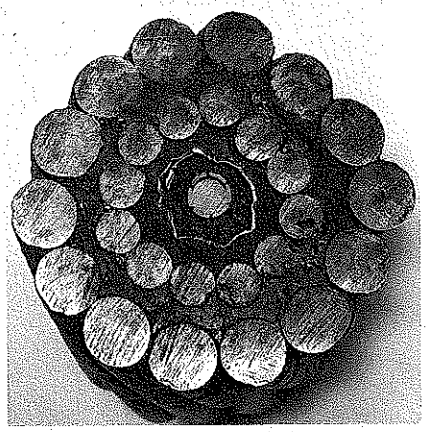


Top row: A fragment of the original trans-Atlantic telegraph cable, which was laid in 1858. Tiffany & Co. jewelers obtained, prepared, and sold 4-in. souvenir lengths for 50 cents. Courtesy of History of Diving Museum, Islamorada, Fla.



Above: This cross section of an early Cook Strait telegraph cable was laid between New Zealand and Australia in the late 19th century. Courtesy of *Te Ara: The Encyclopedia of New Zealand.* www.TeAra.govt.nz/en/photograph/6633/telegraph-cable.





Left: Fragment of the 1863 Persian Gulf cable manufactured by Henleys Telegraph Works Co. Ltd. "Two servings of hemp" were added for strength, according to a *Globe* article at the time.

Lower left: A 1903 cross section (0.9-in. diameter) of the cable that helped provide the first direct telegraph route across the Pacific, from America's West Coast to the Philippines.

Bottom right: Cross section of the 1903 Pacific shore end.

Courtesy of Bill Burns. Private collection. http://atlantic-cable.com.