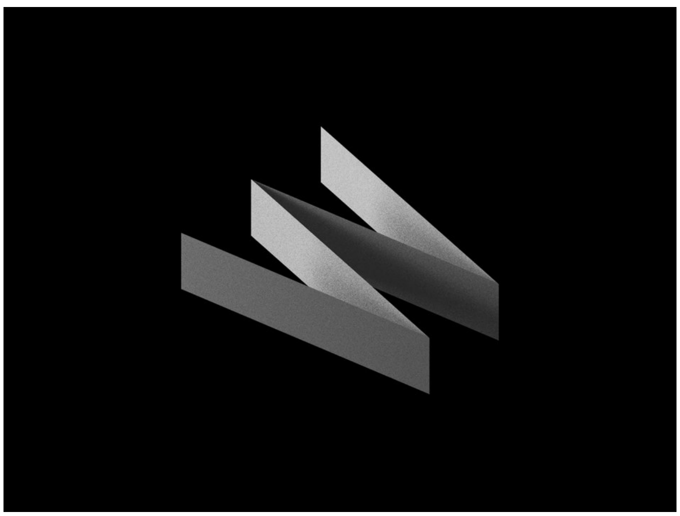
NEAL STEPHENSON 12.01.96 12:00 PM

Mother Earth Mother Board



The hacker tourist ventures forth across the wide and wondrous meatspace of three continents, chronicling the laying of the longest wire on Earth.

In which the hacker tourist ventures forth across the wide and wondrous meatspace of three continents, acquainting himself with the customs and dialects of the exotic Manhole Villagers of Thailand, the U-Turn Tunnelers of the Nile Delta, the Cable Nomads of Lan tao Island, the Slack Control Wizards of Chelmsford, the Subterranean Ex-Telegraphers of Cornwall, and other previously unknown and unchronicled folk; also, biographical sketches of the two long-dead Supreme Ninja Hacker Mage Lords of global

telecommunications, and other material pertaining to the business and technology of Undersea Fiber-Optic Cables, as well as an account of the laying of the longest wire on Earth, which should not be without interest to the readers of *WIRED*.

INFORMATION MOVES, OR we move to it. Moving to it has

nowadays we demand that the information come to us. This can be accomplished in three basic ways: moving physical media around, broadcasting radiation through space, and sending signals through wires. This article is about what will, for a short time anyway, be the biggest and best wire ever made.

Wires warp cyberspace in the same way wormholes warp physical space: the two points at opposite ends of a wire are, for informational purposes, the same point, even if they are on opposite sides of the planet. The cyberspace-warping power of wires, therefore, changes the geometry of the world of commerce and politics and ideas that we live in. The financial districts of New York, London, and Tokyo, linked by thousands of wires, are much closer to each other than, say, the Bronx is to Manhattan.

Today this is all quite familiar, but in the 19th century, when the first feeble bits struggled down the first undersea cable joining the Old World to the New, it must have made people's hair stand up on end in more than just the purely electrical sense—it must have seemed supernatural. Perhaps this sort of feeling explains why when Samuel Morse stretched a wire between Washington and Baltimore in 1844, the first message he sent with his code was "What hath God wrought!"—almost as if he needed to reassure himself and others that God, and not the Devil, was behind it.

During the decades after Morse's "What hath God wrought!" a plethora of different codes, signalling techniques, and sending and receiving machines were patented. A web of wires was spun across every modern city on the globe, and longer wires were strung between cities. Some of the early technologies were, in retrospect, flaky: one early inventor wanted to use 26-wire cables, one wire for each letter of the alphabet. But it quickly became evident that it was best to keep the number of individual wires as low as possible and find clever ways to fit more information onto them.

This requires more ingenuity than you might think—wires have never been perfectly transparent carriers of data; they have always degraded the information put into them. In general, this gets worse as the wire gets longer, and so as the early telegraph networks spanned greater distances, the people building them had to edge away from the seat-of-the-pants engineering practices that, applied in another field, gave us so many boiler explosions, and toward the more scientific approach that is the standard of practice today.

Still, telegraphy, like many other forms of engineering, retained a certain barnyard, improvised quality until the Year of Our Lord 1858, when the terrifyingly high financial stakes and shockingly formidable technical challenges of the first transatlantic submarine cable brought certain long-simmering conflicts to a rolling boil, incarnated the old and new approaches in the persons of Dr. Wildman Whitehouse and Professor William Thomson, respectively, and brought the conflict between them into the highest possible relief in the form of an inquiry and a scandal that rocked the Victorian world. Thomson came out on top, with a new title and name—Lord Kelvin.

Everything that has occurred in Silicon Valley in the last couple of decades also occurred in the 1850s. Anyone who thinks that wild-ass high tech venture capitalism is a late-20th-century California phenomenon needs to read about the maniacs who built the first transatlantic cable projects (I recommend Arthur C. Clarke's book **How the World Was One**). The only things that have changed since then are that the stakes have gotten smaller, the process more bureaucratized, and the personalities less interesting.

Those early cables were eventually made to work, albeit not without founding whole new fields of scientific inquiry and generating many lucrative patents. Undersea cables, and long-distance communications in general, became the highest of high tech, with many of the same connotations as rocket science or nuclear physics or brain surgery would acquire in later decades. Some countries and companies (the distinction between countries and companies is hazy in the telco world) became very good at it, and some didn't. AT&T acquired a dominance of the field that largely continues to this day and is only now being seriously challenged by a project called FLAG: the Fiberoptic Link Around the Globe.

In which the Hacker Tourist encounters: Penang, a microcosm of the Internet. Rubber, Penang's chief commodity, and its many uses: protecting wires from the elements and concupiscent wanderers from harmful DNA. Advantages of chastity, both for hacker tourists and for cable layers. Bizarre Spectacles in the jungles of southern Thailand. FLAG,

its origins and its enemies.

5° 241 24.932' N, 100° 241 19.748' E City of George Town, Island of Penang, Malaysia

FLAG, a fiber-optic cable now being built from England to Japan, is a skinny little cuss (about an inch in diameter), but it is 28,000 kilometers long, which is long even compared to really big things like the planet Earth. When it is finished in September 1997, it arguably will be the longest engineering project in history. Writing about it necessitates a lot of banging around through meatspace. Over the course of two months, photographer Alex Tehrani and I hit six countries and four continents trying to get a grip on this longest, fastest, mother of all wires. I took a GPS receiver with me so that I could have at least a general idea of where the hell we were. It gave me the above reading in front of a Chinese temple around the corner from the Shangri-La Hotel in Penang, Malaysia, which was only one of 100 peculiar spots around the globe where I suddenly pulled up short and asked myself, "What the hell am I doing here?"

You might well ask yourself the same question before diving into an article as long as this one. The answer is that we all depend heavily on wires, but we hardly ever think about them. Before learning about FLAG, I knew that data packets could get from America to Asia or the Middle East, but I had no idea how. I knew that it had something to do with wires across the bottom of the ocean, but I didn't know how many of those wires existed, how they got there, who controlled them, or how many bits they could carry.

According to legend, in 1876 the first sounds transmitted down a wire were Alexander Graham Bell saying "Mr.

Watson, come here. I want you." Compared with Morse's "What hath God wrought!" this is disappointingly banal—as if Neil Armstrong, setting foot on the moon, had uttered the words: "Buzz, could you toss me that rock hammer?" It's as though during the 32 years following Morse's message, people had become inured to the amazing powers of wire.

Today, another 120 years later, we take wires completely for granted. This is most unwise. People who use the Internet (or for that matter, who make long-distance phone calls) but who don't know about wires are just like the millions of complacent motorists who pump gasoline into their cars without ever considering where it came from or how it found its way to the corner gas station. That works only until the political situation in the Middle East gets all screwed up, or an oil tanker runs aground on a wildlife refuge. In the same way, it behooves wired people to know a few things about wires—how they work, where they lie, who owns them, and what sorts of business deals and political machinations bring them into being.

In the hopes of learning more about the modern business of really, really long wires, we spent much of the summer of 1996 in pursuits such as: being arrested by toothless, shotgun-toting Egyptian cops; getting pushed around by a drunken smuggler queen on a Thai train; vaulting over rustic gates to take emergency shits in isolated fields; being kept awake by groovy Eurotrash backpackers singing songs; blowing Saharan dust out of cameras; scraping equatorial mold out of fountain pens; stuffing faded banknotes into the palms of Egyptian service-industry professionals; trying to persuade non-English-speaking taxi drivers that we really did want to visit the beach even though it was pouring rain; and laundering clothes by showering in them. We still missed more than half the countries FLAG touches.

Our method was not exactly journalism nor tourism in the normal sense but what might be thought of as a new field of human endeavor called hacker tourism: travel to exotic locations in search of sights and sensations that only would be of interest to a geek.

I will introduce sections with readings from my trusty GPS in case other hacker tourists would like to leap over the same rustic gates or get rained on at the same beaches

5° 26.325' N, 100° 17.417' E Penang Botanical Gardens

Penang, one of the first sites visited by this hacker tourist partly because of its little-known historical importance to wires, lies just off the west coast of the Malay Peninsula. The British acquired it from the local sultan in the late 1700s, built a pathetic fort above the harbor, and named it, appropriately, after the hapless General Cornwallis. They set up a couple of churches and established the kernel of a judicial system. A vigorous market grew up around them. A few kilometers away, they built a botanical garden.

This seems like an odd set of priorities to us today. But gardens were not mere decorations to the British—they were strategic installations.

The headquarters was Kew Gardens outside of London. Penang was one of the forward outposts, and it became incomparably more important than the nearby fort. In 1876, 70,000 seeds of the rubber tree, painstakingly collected by botanists in the Amazon rain forest, were brought to Kew Gardens and planted in a greenhouse. About 2,800 of them germinated and were shipped to the botanical gardens in Sri Lanka and Penang, where they propagated explosively and were used to establish rubber plantations.

Most of these plantations were on the neighboring Malay Peninsula, a lumpy, bony tentacle of land that stretches for 1,000 miles from Bangkok in the north to Singapore in the south, where it grazes the equator. The landscape is a stalemate between, on one hand, the devastatingly powerful erosive forces of continual tropical rainstorms and dense plant life, and, on the other hand, some really, really hard rocks. Anything with the least propensity to be eroded did so a long time ago and turned into a paddy. What's left are ridges of stone that rise almost vertically from the landscape and are still mostly covered with rain forest, notwithstanding efforts by the locals to cut it all down. The flat stuff is all used for something—coconuts, date palms, banana trees, and above all, rubber.

Until artificial rubber was invented by the colony-impaired Germans, no modern economy could exist without the natural stuff. All of the important powers had tropical colonies where rubber was produced. For the Netherlands, it was Indonesia; for France, it was Indochina; for the British, it was what they then called Malaya, as well as many other places.

Without rubber and another kind of tree resin called gutta-percha, it would not have been possible to wire the world. Early telegraph lines were just naked conductors strung from pole to pole, but this worked poorly, especially in wet conditions, so some kind of flexible but durable insulation was needed. After much trial and error, rubber became the standard for terrestrial and aerial wires while gutta-percha (a natural gum also derived from a tree grown in Malaya) was used for submarine cables. Gutta-percha is humble-looking stuff, a nondescript brown crud that surrounds the inner core of old submarine cables to a thickness of perhaps

1 centimeter, but it was a wonder material back in those days, and the longer it remained immersed in salt water, the better it got.

So far, it was all according to the general plan that the British had in mind: find some useful DNA in the Americas, stockpile it at Kew Gardens, propagate it to other botanical gardens around the world, make money off the proceeds, and grow the economy. Modern-day Penang, however, is a good example of the notion of unintended consequences.

As soon as the British had established the rule of law in Penang, various kinds of Chinese people began to move in and establish businesses. Most of them were Hokkien Chinese from north of Hong Kong, though Cantonese, Hakka, and other groups also settled there. Likewise, Tamils and Sikhs came from across the Bay of Bengal. As rubber trees began to take over the countryside, a common arrangement was for Chinese immigrants to establish rubber plantations and hire Indian immigrants (as well as Malays) as laborers.

The British involvement, then, was more catalytic than anything else. They didn't own the rubber plantations. They merely bought the rubber on an open market from Chinese brokers who in turn bought it from producers of various ethnicities. The market was just a few square blocks of George Town where British law was enforced, i.e. where businessmen could rely on a few basics like property rights, contracts, and a currency.

During and after World War II, the British lost what presence they had here. Penang fell to the Japanese and became a base for German U-Boats patrolling the Indian Ocean. Later, there was a somewhat messy transition to independence involving a communist insurrection and a war with Indonesia. Today, Malaysia is one of Asia's economic supernovas and evidently has decided that it will be second to none when it comes to the Internet. They are furiously wiring up the place and have established JARING, which is the Malaysian Internet (this word is a somewhat tortured English acronym that happens to spell out the Malay word for the Net).

If you have a look at JARING's homepage **(www.jaring.my/jaring)**, you will be confronted by a link that will take you to a page reciting Malaysia's censorship laws, which, like most censorship laws, are ridiculously vague and hence sort of creepy and yet, in the context of the Internet, totally unworkable.

In a way, the architects of JARING are trying to run the Kew Gardens experiment all over again. By adopting the Internet protocol for their national information infrastructure, they have copied the same DNA that, planted in the deregulated telecom environment of the United States, has grown like some unstoppable exotic weed. Now they are trying to raise the same plant inside a hothouse (because they want it to flourish) but in a pot (because they don't want it to escape into the wild).

They seem to have misunderstood both their own history and that of the Internet, which run strangely parallel. Today the streets of George Town, Penang's main city, are so vivid, crowded, and intensely multicultural that by comparison they make New York City look like Colonial Williamsburg. Every block has a mosque or Hindu temple or Buddhist shrine or Christian church. You can get any kind of food, hear any language. The place is thronged, but it's affluent, and it works. It's a lot like the Internet.

Both Penang and the Internet were established basically for strategic military reasons. In both cases, what was built by the military was merely a kernel for a much vaster phenomenon that came along later. This kernel was really nothing more than a protocol, a set of rules. If you wanted to follow those rules, you could participate, otherwise you were free to go elsewhere. Because the protocol laid down a standard way for people to interact, which was clearly set out and could be understood by anyone, it attracted smart, adaptable, ambitious people from all over the place, and at a certain point it flew completely out of control and turned into something that no one had ever envisioned: something thriving, colorful, wildly diverse, essentially peaceful, and plagued only by the congestion of its own success.

JARING's link to the global Internet is over an undersea cable that connects it to the United States. This is typical of many Southeast Asian countries, which are far better connected to the US than they are to one another. But in late June of 1996, a barge called the **Elbe** appeared off the coast of Penang. Divers and boats came ashore, braving an infestation of sea snakes, and floated in a segment of armored cable that will become Malaysia's link to FLAG. The capacity of that cable is theoretically some 5.3 Gbps. Much of this will be used for telephone and other non-Internet purposes, but it can't help but serve as a major floodgate between JARING, the censored pseudo-Internet of Malaysia, and the rest of the Net. After that, it will be interesting to see how long JARING remains confined to its pot.

FLAG facts

The FLAG system, that mother of all wires, starts at Porthcurno, England, and proceeds to Estepona, Spain; through the Strait of Gibraltar to Palermo, Sicily; across the Mediterranean to Alexandria and Port Said, Egypt; overland from those two cities to Suez, Egypt; down the Gulf of Suez and the Red Sea, with a potential branching unit to Jedda, Saudia Arabia; around the Arabian Peninsula to Dubai, site of the FLAG Network Operations Center; across the Indian Ocean to Bombay; around the tip of India and across the Bay of Bengal and the Andaman Sea to Ban Pak Bara, Thailand, with a branch down to Penang, Malaysia; overland across Thailand to Songkhla; up through the South China Sea to Lan Tao Island in Hong Kong; up the coast of China to a branch in the East China Sea where one fork goes to Shanghai and the other to Koje-do Island in Korea, and finally to two separate landings in Japan—Ninomiya and Miura, which are owned by rival carriers.

Phone company people tend to think (and do business) in terms of circuits. Hacker tourists, by contrast, tend to think in terms of bits per second. Converting between these two units of measurements is simple: on any modern phone system, the conversations are transmitted digitally, and the standard bit rate that is used for this purpose is 64 kbps. A circuit, then, in telephony jargon, amounts to a datastream of 64 kbps.

Copper submarine cables of only a few decades ago could carry only a few dozen circuits—say, about 2,500 kbps total. The first generation of optical-fiber cables, by contrast, carries more than 1,000 times as much data—280 Mbps of data per fiber pair. (Fibers always come in pairs. This practice seems obvious to a telephony person, who is in the business of setting up symmetrical two-way circuits, but makes no particular sense to a hacker tourist who tends to think in terms of one-way packet transmission. The split between these two ways of thinking runs very deep and accounts for much tumult in the telecom world, as will be explained later.) The second generation of optical-fiber cables carries 560 Mbps per fiber pair. FLAG and other third-generation systems will carry 5.3 Gbps per pair. Or, in the system of units typically used by phone company people, they will carry 60,000 circuits on each fiber pair.

If you multiply 60,000 circuits times 64 kbps per circuit, you get a bit rate of only 3.84 Gbps, which leaves 1.46 Gbps unaccounted for. This bandwidth is devoted to various kinds of overhead, such as frame headers and error correction. The FLAG cable contains two sets of fiber pairs, and so its theoretical maximum capacity is 120,000 circuits, or (not counting the overhead) just under 8 Gbps of actual throughput.

These numbers really knock 'em dead in the phone industry. To the hacker tourist, or anyone who spends much time messing around with computer networks, they seem distinctly underwhelming. All this trouble and expense for a measly 8 Gbps? You've got to be kidding! Again, it comes down to a radical difference in perspective between telephony people and internet people.

In defense of telephony people, it must be pointed out that they are the ones who really know the score when it comes to sending bits across oceans. Netheads have heard so much puffery about the robust nature of the Internet and its amazing ability to route around obstacles that they frequently have a grossly inflated conception of how many routes packets can take between continents and how much bandwidth those routes can carry. As of this writing, I have learned that nearly the entire state of Minnesota was recently cut off from the Internet for 13 hours because it had only one primary connection to the global Net, and that link went down. If Minnesota, of all places, is so vulnerable, one can imagine how tenuous many international links must be.

Douglas Barnes, an Oakland-based hacker and cypherpunk, looked into this issue a couple of years ago when, inspired by Bruce Sterling's **Islands in the Net**, he was doing background research on a project to set up a data haven in the Caribbean. "I found out that the idea of the Internet as a highly distributed, redundant global communications system is a myth," he discovered. "Virtually all communications between countries take place through a very small number of bottlenecks, and the available bandwidth simply isn't that great." And he cautions: "Even outfits like FLAG don't really grok the Internet. The undersized cables they are running reflect their myopic outlook."

So the bad news is that the capacity of modern undersea cables like FLAG isn't very impressive by Internet standards, but the slightly better news is that such cables are much better than what we have now.Here's how they work: Signals are transmitted down the fiber as modulated laser light with a wavelength of 1,558 nanometers (nm), which is in the infrared range. These signals begin to fade after they have traveled a certain distance, so it's necessary to build amplifiers into the cable every so often. In the case of FLAG, the spacing of these amplifiers ranges from 45 to 85 kilometers. They work on a strikingly simple and elegant principle. Each amplifier contains an approximately 10-meter-long piece of special fiber that has been doped with erbium ions, making it capable of functioning as a laser medium. A separate semiconductor laser built into the amplifier generates powerful light at 1,480 nm—close to the same frequency as the signal beam, but not close enough to interfere with it. This light, directed into the doped fiber, pumps the electrons orbiting around those erbium ions up to a higher energy level.

The signal coming down the FLAG cable passes through the doped fiber and causes it to lase, i.e., the excited electrons drop back down to a lower energy level, emitting light that is coherent with the incoming signal—which is to say that it is an exact copy of the incoming signal, except more powerful.

The amplifiers need power—up to 10,000 volts DC, at 0.9

amperes. Since public 10,000-volt outlets are few and far between on the bottom of the ocean, this power must be delivered down the same cable that carries the fibers. The cable, therefore, consists of an inner core of four optical fibers, coated with plastic jackets of different colors so that the people at opposite ends can tell which is which, plus a thin copper wire that is used for test purposes. The total thickness of these elements taken together is comparable to a pencil lead; they are contained within a transparent plastic tube. Surrounding this tube is a sheath consisting of three steel segments designed so that they interlock and form a circular jacket. Around that is a layer of about 20 steel "strength wires"—each perhaps 2 mm in diameter—that wrap around the core in a steep helix. Around the strength wires goes a copper tube that serves as the conductor for the 10,000-volt power feed. Only one conductor is needed because the ocean serves as the ground wire. This tube also is watertight and so performs the additional function of protecting the cable's innards. It then is surrounded by polyethylene insulation to a total thickness of about an inch. To protect it from the rigors of shipment and laying, the entire cable is clothed in good old-fashioned tarred jute, although jute nowadays is made from plastic, not hemp.

This suffices for the deep-sea portions of the cable. In shallower waters, additional layers of protection are laid on, beginning with a steel antishark jacket. As the shore is approached, various other layers of steel armoring wires are added.

This more or less describes how all submarine cables are being made as of 1996. Only a few companies in the world know how to make cables like this: AT&T Submarine Systems International (AT&T-SSI) in the US, Alcatel in France, and KDD Submarine Cable Systems (KDD-SCS) in Japan, among others. AT&T-SSI and KDD-SCS frequently work together on large projects and are responsible for FLAG. Alcatel, in classic French fasion, likes to go it alone.

This basic technology will, by the end of the century, be carrying most of the information between continents. Copper-based coaxial cable systems are still in operation in many places around the world, but all of them will have reached the end of their practical lifetimes within a few years. Even if they still function, they are not worth the trouble it takes to operate them. TPC-1 (Trans Pacific Cable #1), which connected Japan to Guam and hence to the United States in 1964, is still in perfect working order, but so commercially worthless that it has been turned over to a team at Tokyo University, which is using it to carry out seismic research. The capacity of such cables is so tiny that modern fiber cables could absorb all of their traffic with barely a hiccup if the right switches and routers were in place. Likewise, satellites have failed to match some of the latest leaps in fiber capacity and can no longer compete with submarine cables, at least until such time as low-flying constellations such as Iridium and Teledesic begin operating.

Within the next few years, several huge third-generational optical fiber systems will be coming online: not only FLAG but a FLAG competitor called SEA-ME-WE 3 (Southeast Asia-Middle East-Western Europe #3); TPC-5 (Trans-Pacific Cable #5); APCN (Asia-Pacific Cable Network), which is a web of cables interconnecting Japan, Korea, Hong Kong, Taiwan, Malaysia, Thailand, Indonesia, Singapore, Australia, and the Philippines; and the latest TAT (Transatlantic) cable. So FLAG is part of a trend that will soon bring about a vast increase in intercontinental bandwidth.

What is unusual about FLAG is not its length (although it will be the longest cable ever constructed) or its technology (which is shared by other cables) but how it came into existence. But that's a business question which will be dealt with later. First, the hacker tourist is going to travel a short distance up the Malay Peninsula to southern Thailand, one of the two places where FLAG passes overland. On a world map this looks about as difficult as throwing an extension cord over a sandbar, but when you actually get there, it turns out to be a colossal project

7° 3.467' N,100° 22.489' EFLAG manhole production site, southern Thailand

Large portions of this section were written in a hotel in Ban Hat Yai, Thailand, which is one of the information-transfer capitals of the planet regardless of whether you think of information transfer as bits propagating down an optical fiber, profound and complex religious faiths being transmitted down through countless generations, or genetic material being interchanged between consenting adults. Male travelers approaching Ban Hat Yai will have a difficult time convincing travel agents, railway conductors, and taxi drivers that they are coming only to look at a big fat wire, but the hacker tourist must get used to being misunderstood.

We stayed in a hotel with all the glossy accoutrements of an Asian business center plus a few perks such as partially used jumbo condom packages squirreled away on closet shelves, disconcertingly huge love marks on the sofas, and extraordinarily long, fine, black hairs all over the bathroom. While writing, I sat before a picture window looking out over a fine view of: a well-maintained but completely empty swimming pool, a green Carlsberg Beer billboard written in Thai script, an industrial-scale whorehouse catering to Japanese "businessmen," a rather fine Buddhist temple complex, and, behind that, a district of brand-new high-rise hotels built to cater to the burgeoning information-transfer industry, almost none of which has anything to do with bits and bytes. Tropical storms rolled through, lightning flashed, I sucked down European beers from the minibar and tried to cope with a bad case of information overload. FLAG is a huge project, bigger and more complicated than many wars, and to visit even chunks of this cable operation is to be floored by it.

We first met Jim Daily and Alan Wall underneath that big Carlsberg sign, sitting out in a late-afternoon rainstorm under an umbrella, having a couple of beers—"the only **ferangs** here," as Wall told me on the phone, using the local term for foreign devil. Daily is American, 2 meters tall, blond, blue-eyed, khaki-and-polo-shirted, gregarious, absolutely plain-spoken, and almost always seems to be having a great time. Wall is English, shorter, dark-haired, impeccably suited, cagey, reticent, and dry. Both are in their 50s. It is of some significance to this story that, at the end of the day, these two men unwind by sitting out in the rain and hoisting a beer, paying no attention whatsoever to the industrial-scale whorehouse next door. Both of them have seen many young Western men arrive here on business missions and completely lose control of their sphincters and become impediments to any kind of organized activity. Daily hired Wall because, like Daily, he is a stable family man who has his act together. They are the very definition of a complementary relationship, and they seem to be making excellent progress toward their goal, which is to run two really expensive wires across the Malay Peninsula.

Since these two, and many of the others we will meet on this journey, have much in common with one another, this is as good a place as any to write a general description. They tend to come from the US or the British Commonwealth countries but spend very little time living there. They are cheerful and outgoing, rudely humorous, and frequently have long-term marriages to adaptable wives. They tend to be absolutely straight shooters even when they are talking to a hacker tourist about whom they know nothing. Their openness would probably be career suicide in the atmosphere of Byzantine court-eunuch intrigue that is public life in the United States today. On the other hand, if I had an unlimited amount of money and woke up tomorrow morning with a burning desire to see a 2,000-hole golf course erected on the surface of Mars, I would probably call men like Daily and Wall, do a handshake deal with them, send them a blank check, and not worry about it.

Daily works out of Bangkok, the place where banks are headquartered, contracts are written, and 50-ton cranes are to be had. Alan "the ferang" Wall lives in Ban Hat Yai, the center of the FLAG operation in Thailand, cruising the cable routes a couple of times a week, materializing unpredictably in the heart of the tropical jungle in a perfectly tailored dark suit to inspect, among other things, FLAG's chain of manhole-making villages.

There were seven of these in existence during the summer of 1996, all lying along one of the two highways that run across the isthmus between the Andaman and the South China Seas. These highways, incidentally, are lined with utility poles carrying both power and communications wires. The tops of the poles are guarded by conical baskets about halfway up. The baskets prevent rats from scampering up the poles to chew away the tasty insulation on the wires and poisonous snakes from slithering up to sun themselves on the crossbars, a practice that has been known to cause morale problems among line workers.

The manhole-making village we are visiting on this fine, steamy summer day has a population of some 130 workers plus an unknown number of children. The village was founded in the shade of an old, mature rubber plantation. Along the highway are piles of construction materials deposited by trucks: bundles of half-inch rebar, piles of sand and gravel. At one end of the clearing is a double row of shelters made from shiny new corrugated metal nailed over wooden frames, where the men, women, and children of the village live. On the end of this is an open-air office under a lean-to roof, equipped with a whiteboard—just like any self-respecting high tech company. Chickens strut around flapping their wings uselessly, looking for stuff to peck out of the ground.

When the day begins, the children are bused off to school, and the men and women go to work. The women cut the rebar to length using an electric chop saw. The bars are laid out on planks with rows of nails sticking out of them to form simple templates. Then the pieces of rebar are wired together to create cages perhaps 2 meters high and 1.5 meters on a side. Then the carpenters go to work, lining the cage inside and out with wooden planks. Finally, 13 metric tons of cement are poured into the forms created by the planks. When the planks are taken away, the result is a hollow, concrete obelisk with a cylindrical collar projecting from the top, with an iron manhole cover set into it. Making a manhole takes three weeks.

Meanwhile, along the highway, trenches are being dug—quickly scooped out of the lowland soil with a backhoe, or, in the mountains, laboriously jackhammered into solid rock. A 50-ton crane comes to the village, picks up one manhole at a time using lifting loops that the villagers built into its top, and sets it on a flatbed truck that transports it to one of the wider excavations that are spaced along the trench at intervals of 300 to 700 meters. The manholes will allow workers to climb down to the level of the buried cable, which will stretch through a conduit running under the ground between the manholes.

The crane lowers the manhole into the excavation. A couple of hard-hatted workers get down there with it and push it this way and that, getting it lined up, while other workers up on the edge of the pit help out by shoving on it with a big stick. Finally it settles gingerly into place, atop its prepoured pad. The foreman clambers in, takes a transparent green disposable lighter from his pocket, and sets it down sideways on the top of the manhole. The liquid butane inside the lighter serves as a fluid level, verifying that the manhole is correctly positioned.

With a few more hours' work, the conduits have been mated with the tubes built into the walls of the manhole and the surrounding excavation filled in so that nothing is left except some disturbed earth and a manhole cover labeled CAT: Communications Authority of Thailand. The eventual result of all this work will be two separate chains of manholes (931 of them all told) running parallel to two different highways, each chain joined by twin lengths of conduit—one conduit for FLAG and one for CAT.

Farther west, another crew is at work, burdened with three enormous metal spools carrying flexible black plastic conduit having an inside diameter of an inch. The three spools are set up on stands near a manhole, the three ducts brought together and tied into a neat bundle by workers using colorful plastic twine. Meanwhile, others down in the manhole are wrestling with the world's most powerful peashooter: a massive metal pipe with a screw jack on its butt end. The muzzle of the device is inserted into one of the conduits on the manhole wall and the screw jack is tightened against the opposite wall to hold it horizontal. Next the peashooter is loaded: a big round sponge with a rope tied to it is inserted into an opening on its side. The rope comes off a long spool. Finally, a hefty air compressor is fired up above ground and its outlet tube thrown down into the manhole and patched into a valve on this pipe. When the valve is opened, compressed air floods the pipe behind the round sponge, which shoots forward like a bullet in a gun barrel, pulling the rope behind it and causing the reel to spin wildly like deep-sea fishing tackle that has hooked a big tuna.

"Next manhole! Next manhole!" cries the foreman excitedly, and pedestrians, bicyclists, motor scooters, and (if inspectors or hacker tourists are present) cars parade down the highway, veering around water buffaloes and goats and chickens to the next manhole, some half a kilometer away, where a torrent of water, driven before the sponge, is blasting out of a conduit and slamming into the opposite wall. One length of the conduit can hold some 5 cubic meters of water, and the sponge, ramming down the tube like a piston, forces all of it out. Finally the sponge pops out of the hole like a pea from a peashooter, bringing the rope with it. The rope is used to pull through a thicker rope, which is finally connected to the triple bundle of thin duct at one end and to a pulling motor at the other. This pulling motor is a slowly turning drum with several turns of rope around it.

Now the work gets harder: at the manhole with the reels, some workers bundle and tie the ducts as they unroll while others, down in the hole, bend them around a difficult curve and keep them feeding smoothly into the conduit. At the other end, a man works with the puller, keeping the tension constant and remaining alert for trouble. Back at the reels, the thin duct occasionally gets wedged between loose turns on the reel, and everything has to be stopped. Usually this is communicated to the puller via walkie-talkie, but when the afternoon rains hit, the walkie-talkies don't work as well, and a messenger has to buzz back and forth on a motor scooter. But eventually the triple inner duct is pulled through both of the conduits, and the whole process can begin again on the next segment.

Daily and Wall preside over this operation, which is Western at the top and pure Thai at the ground level, with a gradual shading of cultures in between. FLAG has dealings in many countries, and the arrangement is different in each one. Here, the top level is a 50-50 partnership between FLAG and Thailand's CAT. They bid the project out to two different large contractors, each of whom hired subcontractors with particular specialties who work through sub-sub-contractors who hire the workers, get them to the site, and make things happen. The incentives are shaped at each level so that the contractors will get the job done without having to be micromanaged, and the roads seem to be crawling with inspectors representing various levels of the project who make sure that the work is being done according to spec (at the height of this operation, 50 percent of the traffic on some of these roads was FLAG-related).

The top-level contracts are completely formalized with detailed specifications, bid bonds, and so on, and business at this level is done in English and in air-conditioned offices. But by the time you get to the bottom layer, work is being done by people who, although presumably just as intelligent as the big shots, are fluent only in Thai and not especially literate in any language, running around in rubber flip-flops, doing business on a handshake, pulling wads of bills out of their pockets when necessary to pay for some supplies or get drinks brought in. Consequently, the way in which the work is performed bears no resemblance whatsoever to the way it would be done in the United States or any other developed country. It is done the Thai way.

Not one but two entirely separate pairs of conduits are being created in this fashion. Both of them run from the idyllic sandy beach of Ban Pak Bara on the west to the paradisiacal sandy beach of Songkhla on the east—both of them are constructed in the same way, to the same specifications. Both of them run along highways. The southern route takes the obvious path, paralleling a road that runs in a relatively straight line between the two endpoints for 170 kilometers. But the other route jogs sharply northward just out of Ban Pak Bara, runs up the coast for some distance, turns east, and climbs up over the bony spine of the peninsula, then turns south again and finally reaches Songkhla after meandering for some 270 kilometers. Unlike the southern route, which passes almost exclusively over table-flat paddy land, easily excavated with a backhoe, the northern route goes for many kilometers over solid rock, which must be trenched with jackhammers and other heavy artillery, filled with galvanized steel conduit, and then backfilled with gravel and concrete.

This raises questions. The questions turn out to have interesting answers. I'll summarize them first and then go into detail. Q: Why bother running two widely separated routes over theMalay Peninsula?

A: Because Thailand, like everywhere else in the world, is full ofidiots with backhoes.

Q: Isn't that a pain in the ass?

A: You have no idea.

Q: Why not just go south around Singapore and keep the cable in the water, then?

A: Because Singapore is controlled by the enemy.

Q: Who is the enemy?

A: FLAG's enemies are legion.

The reason for the difficult northern route is FLAG's pursuit of diversity, which in this case is not a politically correct buzzword (though FLAG also has plenty of that kind of diversity) but refers to the principle that one should have multiple, redundant paths to make the system more robust. Diversity is not needed in the deep ocean, but land crossings are viewed as considerably more risky. So FLAG decided, early on, to lay two independent cables on two different routes, instead of one.

The indefatigable Jim Daily, along with his redoubtable inspector Ruzee, drove us along every kilometer of both of these routes over the course of a day and a half. "Let me ask you a naïve question," I said to him, once I got a load of the big rock ridge he was getting ready to cut a trench through. "Why not just put one cable on one side of that southern highway and another cable on the opposite side?" I found it hard to imagine a backhoe cutting through both sides of the highway at once."

They just wanted to be sure that there was no conceivable disaster that could wipe out both routes at the same time," he shrugged.

FLAG has envisioned every possible paranoid disaster scenario that could lead to a failure of a cable segment and has laid action plans that will be implemented if this should happen. For example, it has made deals with its competitors so that it can buy capacity from them, if it has to, while it repairs a break (likewise, the competitors might reserve capacity from FLAG for the same reason). Despite all this, FLAG is saying in this case: "We are going to cut a trench across a 50-mile-wide piece of rock because we think it will make our cable infinitesimally more reliable." Essentially, they have to do it, because otherwise no one will entrust valuable bits to their cable system.

Why didn't they keep it in the water? Opinions vary on this: pro-FLAG people argue that the Straits, with all of their ship traffic, are a relatively hazardous place to put a submarine cable and that a terrestrial crossing of the Malay Peninsula is a tactical masterstroke. FLAG skeptics will tell you that the terrestrial crossing is a necessity imposed on them because Singapore Telecom made the decision that they didn't want to be connected to FLAG.

Instead, Singapore Telecom and France Telecom have been promoting SEA-ME-WE 3, that Southeast Asia-Middle East-Western Europe 3 cable, a system whose target date is 1999, two years later than FLAG. SEA-ME-WE 1 and 2 run from France to Singapore and 3 was originally planned to cover the same territory, but now its organizers have gotten other telecoms, such as British Telecom, involved. They hope that SEA-ME-WE 3 will continue north from Singapore as far as Japan, and north from France to Great Britain, covering generally the same route as FLAG. FLAG and SEA-ME-WE 3 are, therefore, direct competitors.

The competition is not just between two different wires. It is a competition between two entirely different systems of doing business, two entirely different visions of how the telecommunications industry should work. It is a competition, also, between AT&T (the juggernaut of the field, and the power behind most telecom-backed systems) and Nynex (the Baby Bell with an Oedipus complex and the power behind FLAG). Nynex and AT&T have their offices a short distance from each other in Manhattan, but the war between them is being fought in trenches in Thailand, glass office towers in Tokyo, and dusty government ministries in Egypt.

The origin of FLAG

Kessler Marketing Intelligence Corp. (KMI) is a Newport, Rhode Island, company that has developed a specialty in tracking the worldwide submarine cable system. This is not a trivial job, since there are at least 320 cable systems in operation around the world, with old ones being retired and new ones being laid all the time. KMI makes money from this by selling a document titled "Worldwide Summary of Fiberoptic Submarine Systems" that will set you back about US$4,500 but that is a must-read for anyone wanting to operate in that business. Compiling and maintaining this document gives a rare Olympian perspective on the world communications system.

In the late 1980s, as KMI looked at the cables then in existence and the systems that were slated for the next few years, they noticed an almost monstrous imbalance.

The United States would, by the late 1990s, be massively connected to Europe by some 200,000 circuits across the Atlantic, and just as massively connected to Asia by a roughly equal number of circuits across the Pacific. But between Europe and Asia there would be fewer than 20,000 circuits.

Cables have always been financed and built by telecoms, which until very recently have always been government-backed monopolies. In the business, these are variously referred to as PTTs (Post, Telephone, and Telegraphs) or PTAs (Post and Telecom Authorities) or simply as "the clubs." The dominant club has long been AT&T—especially in the years since World War II, when most of the international telecommunications system was built.

Traditionally, the way a cable system gets built is that AT&T meets with other PTTs along the proposed route to negotiate terms (although in the opinion of some informed people who don't work for AT&T, "dictate" comes closer to the truth than "negotiate"). The capital needed to construct the cable system is ponied up by the various PTTs along its route, which, consequently, end up collectively owning the cable and all of its capacity. This is a tidy enough arrangement as those telecoms traditionally "own" all of the customers within their borders and can charge them whatever it takes to pay for all of those cables. Cables built this way are now called "club cables."

Given America's postwar dominance of the world economy and AT&T's dominance of the communications system, it becomes much easier to understand the huge bandwidth imbalance that the analysts at KMI noticed. Actually, it would be surprising if this imbalance didn't exist. If the cable industry worked on anything like a free-market basis, this howling chasm in bandwidth between Europe and Asia would be an obvious opportunity for entrepreneurs. Since the system was, in fact, controlled by government monopolies, and since the biggest of those monopolies had no particular interest in building a cable that entirely bypassed its territory, nothing was likely to happen.

But then something did happen. KMI, whose entire business is founded on knowing and understanding the market, was ideally positioned, not just to be aware of this situation, but also to crunch the numbers and figure out whether it constituted a workable business opportunity. In 1989, it published a study on worldwide undersea fiber-optic systems that included some such calculations. Based on reasonable assumptions about the cost of the system, its working lifetime, and the present cost of communications on similar systems, KMI reckoned that if a state-of-the-art cable were laid from the United Kingdom to the Middle East it would pay back its investors in two to five years. Setting aside for a moment the fact that it went against all the traditions of the industry, there was no reason in principle why a privately financed cable could not be constructed to fill this demand. Investors would pool the capital, just as they would for any other kind of business venture. They would buy the cable, pay to have it installed, sell the capacity to local customers, and make money for their shareholders.

The study was read by Gulf Associates, a group of New York-based moneyed Iranian expats who are always looking for good investments. Gulf Associates checked out KMI's prefeasibility study to get an idea of what the parameters of such a system would be. Based on that, other companies, such as Dallah Al-Baraka (a Saudi investment company), Marubeni Corp. (a Tokyo trading company), and

Nynex got involved. The nascent consortium paid KMI to perform a full feasibility study. Neil Tagare, the former vice president for KMI, visited 25 countries to determine their level of need for such a cable. The feasibility study was completed in late 1990 and looked favorable. The consortium grew to include the Asian Infrastructure Fund of Hong Kong and Telecom Holding Co. Ltd. of Thailand. The scope of the project grew also, extending not just to the Middle East but all the way to Tokyo.

Nynex took on the role of managing sponsor for the FLAG project. A new company called Nynex Network Systems (Bermuda) Ltd. was formed to serve as the worldwide sales representative for FLAG, and FLAG's world headquarters was sited in Bermuda. This might seem a bit peculiar given that none of the money comes from Bermuda, the cable goes nowhere near Bermuda, and Nynex is centered in the northeastern United States. But since FLAG is ultimately owned and controlled by a Bermuda company and the capacity on the cable is sold out of Bermuda, the invoices all come out of Bermuda and the money all comes into Bermuda, which by an odd coincidence happens to be a major corporate tax haven.

Nynex also has responsibility for building the FLAG cable system. One might think that a Baby Bell such as Nynex would be a perfect choice for this kind of work, but, in fact, Nynex owned none of the factories needed to manufacture cable, none of the ships needed to lay it, and not enough of the expertise needed to install it. Nynex does know a thing or two about laying and operating terrestrial cable systems—during the mid-1990s, for example, it wired large parts of the United Kingdom with a "cable television" system that is actually a generalized digital communication network. But transoceanic submarine cables were outside of its traditional realm.

On the other hand, during the early '90s, Nynex found itself stymied from competing in the United States because of regulatory hassles and began looking overseas for markets in which to expand. By the time FLAG was conceived, therefore, Nynex had begun to gain experience in the countless pitfalls of doing business in the worldwide telecommunications business, making up a little bit of AT&T's daunting lead.

FLAG's business arrangements were entirely novel. The entire FLAG concept was unfeasible unless agreements could be made with so-called landing parties in each country along the route. The landing party is the company that owns the station where the cable comes ashore and operates the equipment that patches it into the local telecommunications system. The obvious choice for such a role would be a PTT. But many PTTs were reluctant to participate, partly because this novel arrangement struck them as dubious and partly because they weren't going to end up monopolizing the cable.

Overcoming such opposition was essentially a sales job. John Mercogliano, a high-intensity New Yorker who is now vice president—Europe, Nynex Network Systems (Bermuda) Ltd., developed a sales pitch that he delivers too rapidly for any hacker tourist to write down but goes something like this: "In the old days AT&T came in, told you how much to pay, and you raised the money, assumed all of the risk, and owned the cable. But now FLAG's coming in with investors who are going to put in $600 million of their own cash and borrow a billion more without any guaranteed sales, assuming all of the risk. You buy only as much capacity on FLAG as you want, and meanwhile you have retained your capital, which you can use to upgrade your outdated local infrastructure and provide better service to your customers —now what the hell is wrong with that?"

The question hangs in the air provocatively. What the hell is wrong with it? Put this way, it seems unbeatable. But a lot of local telecoms turned FLAG down anyway—at least at first. Why?

The short answer is that I'm not allowed to tell you. The long answer requires an explanation of how a hacker tourist operates; how his methods differ from those of an actual journalist; and just how weird the global telecom business is nowadays.

Let's take the last one first. The business is so tangled that no pure competition exists. There are no Coke-versus-Pepsi dichotomies. Most of the companies mentioned in this story are actually whole families of companies, and most of those have their fingers in pies in dozens of countries all around the globe. Any two companies that compete in one arena are, at the same time, probably in bed with each other on many other levels. As badly as they might want to slag each other in the press, they dare not.

So, like those "high-ranking officials" you're always reading about in news reports from Washington, they all talk on background. Anyone who wants to write about this business will come off as either a genius with an encyclopedic brain or a pathological liar with an axe to grind—depending on the reader's point of view—because all truly interesting information is dished out strictly on background.

Perhaps a real journalist would go into Woodward-and-Bernstein mode, find a Deep Throat, and lay it all bare. But I'm not a real journalist: I'm a hacker tourist, and trying to work up an exposé on monopolistic behavior by big bad telecoms would only get in the way of what are, to me, the more interesting aspects of this story.

So I'll just say that a whole lot of important and well-informed people in the telecom business, all over the planet, are laboring under the strange impression that AT&T used its power and influence to discourage smaller telecoms in other countries from signing deals with FLAG.

In the old days, this would have prevented FLAG from ever coming into existence. But these are the new days, telecom deregulation is creeping slowly across the planet, and many PTTs now have to worry about competition. So the results of the FLAG sales pitch varied from country to country. In some places, like Singapore, FLAG never made an agreement with anyone and had to bypass the country entirely. In other places, the PTT broke ranks with AT&T and agreed to land FLAG. In others, the PTT turned it down but an upstart competitor decided to land FLAG instead, and in still others, the PTT declined at first, and then got so worried about the upstart competitor that it changed its mind and decided to land FLAG after all.

It would be very easy for you, dear reader, to underestimate what a sea change this all represents for the clubs. They are not accustomed to having to worry about competition—it doesn't come naturally to them. The typical high-ranking telecom executive is more of a government bureaucrat than a businessperson, and the entire scenario laid out above is irregular, messy, and disturbing to someone like that. A telecrat's reflex is to assume, smugly, that new carriers simply don't matter, because no matter how much financing and business acumen they may have, no matter how great the demand for their services may be, and no matter how crappy the existing service is, the old PTT still controls the cable, which is the only way to get bits out of the country. But in the FLAG era, if the customers go to another carrier, that carrier will find a way to get the needed capacity somehow—at which point it is too late for the PTT.

The local carriers, therefore, need to stop thinking globally and start thinking locally. That is, they need to leave long-range cable laying to the entrepreneurs, to assume that the bandwidth will always somehow be there, and to concentrate on upgrading the quality of their customer service—in particular, the so-called last mile, the local loop that ties customers into the Net.

By the end of 1994, FLAG's Construction and Maintenance Agreement had been signed, and the project was for real. Well before this point, it had become obvious to everyone that FLAG was going to happen in some form, so companies that initially might have been hostile began looking for ways to get in on the action. The manufacture of the cable and the repeaters had been put out to bid in 1993 and had turned into a competition between two consortia, one consisting of AT&T Submarine Systems and KDD Submarine Cable Systems, and the other formed around Alcatel and Fujitsu. The former group ended up landing the contract. So AT&T, which evidently felt threatened by the whole premise of the FLAG project and according to some people had tried to quash it, ended up with part of the contract to manufacture the cable.

In which the Hacker Tourist returns (temporarily) to British soil in the Far East. The (temporary) center of the cable-laying universe. Hoisting flagons with the élite cable-laying fraternity at a waterfront establishment. Classic reprise of the ancient hacker-versus-suit drama.Historical exploits of the famous William Thomson and the infamous Wildman Whitehouse. Their rivalry, culminating in the destruction of the first transatlantic cable. Whitehouse disgraced, Thomson transmogrified into Lord Kelvin ....

22° 15.745' N, 114° 0.557' ESilvermine Bay, Lan Tao Island,?b> Hong Kong

"Today, Lan Tao Island is the center of the cable-laying universe," says David M. Handley, a 52-year-old Southerner who, like virtually all cable-laying people, is talkative, endlessly energetic, and gives every indication of knowing exactly what he's doing. "Tomorrow, it'll be someplace else." We are chug-a-lugging large bottles of water on a public beach at Tong Fuk on the southern coast of Lan Tao, which is a relatively large (25 kilometers long) island an hour's ferry ride west of Hong Kong Island. Arrayed before us on the bay is a collection of vessels that, to a layman, wouldn't look like the center of a decent salvage yard, to say nothing of the cable-laying universe. But remember that "layman" is just a polite word for "idiot."

Closest to shore, there are a couple of junks and sampans. Mind you, these are not picturesque James Clavell junks with red sails or Pearl Buck sampans with pole-wielding peasants in conical hats. The terms are now used to describe modern, motorized vessels built vaguely along the same lines to perform roughly the same functions: a junk is a large, square-assed vessel, and a sampan is a small utility craft with an enclosed cabin. Farther out, there are two barges: slabs with cranes and boxy things on them. Finally, there are several of what Handley calls LBRBs (Little Bitty Rubber Boats) going back and forth between these vessels and the beach. Boeing hydrofoils and turbo cats scream back and forth a few miles out, ferrying passengers among various destinations around the Pearl Delta region. It's a hot day, and kids are swimming on the public beach, prudently staying within the line of red buoys marking the antishark net. Handley remarks, offhandedly, that five people have been eaten so far this year. A bulletin board, in English and Chinese, offers advice: "If schooling fish start to congregate in unusually large numbers, leave the water."

This bay is the center of the cable-laying universe because cable layers have congregated here in unusually large numbers and because of those two barges, which are a damn sight more complicated and expensive than you would ever guess from looking at them. These men (they are all men) and equipment have come from all over the world, to land not only FLAG but also, at the same time, another of those third-generation fiber-optic cables, APCN (Asia-Pacific Cable Network).

In contrast to other places we visited, virtually no local labor is being used on Lan Tao. There is hardly a Chinese face to be seen around the work site, and when you do see an Asian it tends to be either an Indonesian member of a barge crew or a Singaporean of Chinese or Indian ancestry. Most of the people here are blue-eyed and sunburned. A good half of them have accents that originate from the British Isles. The remainder are from the States (frequently Dixie), Australia, or New Zealand, with a smattering from France and Germany.

Both FLAG and APCN are just passing through Hong Kong, not terminating here, and so each has to be landed twice (one segment coming in and one segment going back out). In FLAG's case, one segment goes south to Songkhla, Thailand, and the other goes north toward Shanghai and Korea. It wouldn't be safe to land both segments in the same place, so there are two separate landing sites, with FLAG and APCN cables running side by side at each one. One of the sites is at the public beach, which is nice and sandy. The other site is a few hundred meters away on a cobble beach—a hill of rounded stones, fist- to football-sized, rising up out of the surf and making musical clinking noises as the waves smash them up and down the grade. This is a terrible place to land a cable (Handley: "If it was easy, everybody would do it!") but, as in Thailand, diversity is the ultimate trump card. Planted above the hill of cobbles is a brand-new cable station bearing the Hong Kong Telecom logo, only one of the spoils soon to be reaped by the People's Republic of China when all this reverts to its control next year.

Lan Tao Island, like most other places where cables are landed, is a peculiar area, long home to smugglers and pirates. Some 30,000 people live here, mostly concentrated around Silvermine Bay on the island's eastern end, where the ferries come in every hour or so from Hong Kong's central district, carrying both islanders and tourists. The beaches are lovely, except for the sharks, and the interior of the island is mostly unspoiled parkland, popular among hikers. Hong Kong's new airport is being built on reclaimed land attached to the north side of the island, and a monumental chain of bridges and tunnels is being constructed to connect it with the city. Other than tourist attractions, the island hosts a few oddities such as a prison, a Trappist monastery, a village on stilts, and the world's largest outdoor bronze Buddha.

Cable trash, as these characters affectionately call themselves, shuttle back and forth between Tong Fuk and Silvermine Bay. They all stay at the same hotel and tend to spend their off hours at Papa Doc's (no relation to the Haitian dictator), a beachfront bar run by expats (British) for expats (Australians, Americans, Brits, you name it). Papa Doc's isn't just for cable layers. It also meets the exacting specifications of exhausted hacker tourists. It's the kind of joint that Humphrey Bogart would be running if he had washed ashore on Lan Tao in the mid-1990s wearing a nose ring instead of landing in Casablanca in the 1940s wearing a fedora.

One evening, after Handley and I had been buying each other drinks at Papa Doc's for a while, he raised his glass and said, "To good times and great cable laying!" This toast, while no doubt uttered with a certain amount of irony, speaks volumes about cable professionals.

For most of them, good times and great cable laying are one and the same. They make their living doing the kind of work that automatically weeds out losers. Handley, for example, was a founding member of SEAL Team 2 who spent 59 months fighting in Vietnam, laid cables for the Navy for a few more years, and has done similar work in the civilian world ever since. In addition to being an expert diver, he has a master mariner's license good up to 1,500 tons, which is not an easy thing to get or maintain. He does all his work on a laptop (he claims that it replaced 14 employees) and is as computer-literate as anyone I've known who isn't a coder.

Handley is unusual in combining all of these qualities into one person (that's why he's the boss of the Lan Tao Island operation), but the qualities are as common as tattoos and Tevas around the tables of Papa Doc's. The crews of the cable barges tend to be jacks-of-all-trades: ship's masters who also know how to dive using various types of breathing rigs or who can slam out a report on their laptops, embed a few digital images in it, and email it to the other side of the world over a satellite phone, then pick up a welding torch and go to work on the barge. If these people didn't know what they were doing, there's a good chance they would be dead by now or would have screwed up a cable lay somewhere and washed out of the industry.

Most of the ones here work on what amounts to a freelance basis, either on their own or as part of small firms. Handley, for example, is Director of Technical Services for the ITR Corporation, which, among other functions, serves as a sort of talent agency for cable-layers, matching supply of expertise to demand and facilitating contracts. Most of the divers are freelancers, hired temporarily by companies that likewise move from one job to another. The business is as close to being a pure meritocracy as anything ever gets in the real world, and it's only because these guys know they are good that they have the confidence to call themselves cable trash.

It was not always thus. Until very recently, cable-laying talent was monopolized by the clubs. This worked just fine when every cable was a club cable, created by monopolies for monopolies. In the last couple of years, however, two changes have occurred at once: FLAG, the first major privately financed cable, came along; and at the same time, many experienced cable layers began to go into business for themselves, either because of voluntary retirement or downsizing. There clearly is a synergy between these two trends.

The roster of FLAG's Tong Fuk cable lay contains around 44 people, half of whom are crew members on either the cable barge **Elbe** or the accompanying tug **Ocean East**. The rest of them are here representing various contractors involved in the project. It would be safe to assume that at least that many are working on the APCN side for a grand total of around 100.

The size of the fraternity of cable layers is estimated by Handley to be less than 500, and the number is not increasing. A majority work full time for one of the clubs. Perhaps a couple of hundred of them are freelancers, though this fraction gives every indication of rising as the club employees resign and go to work as contractors, frequently doing the same work for the same company. "No one can afford to hire these folks for long periods of time," Handley says. But their pay is not exceptionally high: benefits, per diem, and expenses plus a daily rate—but a day might be anything from 0 to 24 hours of work. For a diver the rate might be $200 per day; for the master of a barge, tug, or beach $300; and for the experts running the show and repping for contractors or customers it's in the range of $300 to $400.

The arrival of a shore-landing operation at a place like Lan Tao Island must look something like this to the locals: suddenly, it is difficult to obtain hotel rooms because a plethora of small, unheard-of offshore corporations have blocked out a couple of dozen rooms for a couple hundred nights. Sunburned Anglos begin to arrive, wearing T-shirts and carrying luggage emblazoned with the logos of Alcatel, AT&T, or Cable & Wireless. They fly in from all points of the compass, speaking in Southern drawls or Australian twangs or Scottish burrs and sometimes bringing their wives or girlfriends, not infrequently Thai or Filipina. The least important of them has a laptop and a cell phone, but most have more advanced stuff like portable printers, GPS units, and that ultimate personal communications device, the satellite telephone, which works anywhere on the planet, even in the middle of the ocean, by beaming the call straight up to a satellite.

Sample conversation at Papa Doc's:

Envious hacker tourist: "How much does one of those satellite phones cost, anyway?"

Leathery, veteran cable layer: "Who gives a shit?"

Within a day or two, the cable layers have established an official haunt: preferably a place equipped with a dartboard and a few other amenities very close to the waterfront so they can keep an eye on incoming traffic. There they can get a bite to eat or a drink and pay for it on the spot so that when their satellite phones ring or when a tugboat chugs into the bay, they can immediately dash off to work. These men work and play at completely erratic and unpredictable hours. They wear shorts and sandals and T-shirts and frequently sport tattoos and hence could easily be mistaken, at a glance, for vacationing sailors. But if you can get someone to turn down the volume on the jukebox, you can overhear them learnedly discoursing on flaw propagation in the crystalline structure of boron silicate glass or on seasonal variation of currents in the Pearl River estuary, or on what a pain in the ass it is to helm a large ship through the Suez Canal. Their conversation is filled with references to places like Tunisia, Diego Garcia, the North Sea, Porthcurno, and Penang.

One day a barge appears off the cove, and there is a lot of fussing around with floats, lots of divers in the water. A backhoe digs a trench in the cobble beach. A long skinny black thing is wrestled ashore. Working almost naked in the tropical heat, the men bolt segmented pipes around it and then bury it. It is never again to be seen by human eyes. Suddenly, all of these men pay their bills and vanish. Not long afterward, the phone service gets a hell of a lot better.

On land, the tools of cable laying are the tools of civil engineers: backhoes, shovels, cranes. The job is a matter of digging a ditch, laying duct, planting manholes. The complications are sometimes geographical but mostly political. In deep water, where the majority of FLAG is located, the work is done by cable ships and has more in common with space exploration than with any terrestrial activity. These two realms could hardly be more different, and yet the transition between them—the shore landing—is completely distinct from both.

Shallow water is the most perilous part of a cable's route. Extra precautions must be taken in the transition from deep water to the beach, and these precautions get more extreme as the water gets more shallow. Between 1,000 and 3,000 meters, the cable has a single layer of armor wires (steel rods about as thick as a pencil) around it. In less than 1,000 meters of water, it has a second layer of armor around the first. In the final approach to the shoreline, this double-armored cable is contained within a massive shell of articulated cast-iron pipe, which in turn is buried under up to a meter of sand.

The articulated pipe comes in sections half a meter long, which have to be manually fit around the cable and bolted together. Each section of pipe interlocks with the ones on either end of it. The coupling is designed to bend a certain amount so that the cable can be snaked around any obstructions to its destination: the beach manhole. It will bend only so much, however, so that the cable's minimum radius of curvature will not be violated.

At the sandy beach this manual work was done out in the surf by a team of English freelance divers based out of Hong Kong. At the cobble beach, it was done in a trench by a bikini-underwear-clad Frenchman with a New Zealand passport living in Singapore, working in Hong Kong, with a Singaporean wife of Chinese descent. Drenched with sweat and rain and seawater, he wrestles with the cast-iron pipe sections in a cobblestone ditch, bolting them patiently together. A Chinese man in a suit picks his way across the cobbles toward him, carrying an oversized umbrella emblazoned with the logo of a prominent stock brokerage, followed by a minion. Although this is all happening in China, this is the first Chinese person who has appeared on the beach in a couple of days. He is an executive from the phone company, coming to inspect the work. After a stiff exchange of pleasantries with the other cable layers on the beach, he goes to the brink of the trench and begins bossing around the man with the half-pipes, who, knowing what's good for him, just keeps his mouth shut while maintaining a certain bearing and dignity beside which the executive's suit and umbrella seem pathetic and vain.

To a hacker tourist, the scene is strikingly familiar: it is the ancient hacker-versus-suit drama, enacted for the millionth time but sticking to its traditional structure as strictly as a Noh play or, for that matter, a Dilbert cartoon. Cable layers, like hackers, scorn credentials, etiquette, and nice clothes. Anyone who can do the work is part of the club. Nothing else matters. Suits are a bizarre intrusion from an irrational world. They have undeniable authority, but heaven only knows how they acquired it. This year, the suits are from Hong Kong, which means they are probably smarter than the average suit. Pretty soon the suits will be from Beijing, but Beijing doesn't know how to lay cable either, so if they ever want to get bits in or out of their country, they will have to reach an understanding with these guys.

At Tong Fuk, FLAG is encased in pipe out to a distance of some 300 meters from the beach manhole. When the divers have got all of that pipe bolted on, which will take a week or so, they will make their way down the line with a water jet that works by fluidizing the seabed beneath it, turning it into quicksand. The pipe sinks into the quicksand, which eventually compacts, leaving no trace of the buried pipe.

Beyond 300 meters, the cable must still be buried to protect it from anchors, tickler chains, and otter boards (more about this later). This is the job of the two barges we saw off Tong Fuk. One, the **Elbe**, was burying FLAG. The other was burying APCN. **Elbe** did its job in one-third the time, with one-third the crew, perhaps exemplifying the difference between FLAG's freelance-based virtual-corporation business model versus the old club model. The **Elbe** crew is German, British, Filipino, Singaporean-of-Indian-ancestry, New Zealander, and also includes a South African diver.

In the center of the barge is a tank where the cable is spooled. The thick, heavy armored cable that the **Elbe** works with is covered with a jacket of tarred jute, which gives it an old-fashioned look that belies its high tech optical-fiber innards. The tar likes to melt and stick the cable together, so each layer of cable in the tank is separated from its neighbors by wooden slats, and buckets of talc are slathered over it. The cable emerges from the open top of the tank and passes through a series of rollers that curve around, looking very much like a miniature roller-coaster track—these are built in such a way as to bend the cable through a particular trajectory without violating its minimum radius of curvature. They feed it into the top of the injector unit.

The injector is a huge steel cleaver, 7 meters high and 2 or 3 meters broad, rigged to the side of the barge so it can slide up and down and thus be jammed directly into the seabed. But instead of a cutting blade on its leading edge, it has a row of hardened-steel injector nozzles that spurt highly pressurized water, piped in from a huge pump buried in the **Elbe**'s engine room. These nozzles fluidize the seabed and thus make it possible for the giant blade to penetrate it. Along the trailing edge of the blade runs a channel for the cable so that as the blade works its way forward, the cable is gently laid into the bottom of the slit. The barge carries a set of extensions that can be bolted onto the top of the injector so it can operate in water as deep as 40 meters, burying the cable as deep as 9 meters beneath the seabed. This sufficed to lay the cable out for a distance of 10 kilometers from Tong Fuk. Later, another barge, the **Chinann**, will come to continue work out to 100 meters deep and will bury both legs of the FLAG cable for another 60 kilometers out to get them through a dangerous anchorage zone.

The **Elbe** has its own tugboat, the **Ocean East**, staffed with an Indonesian crew. Relations between the two vessels have been a bit tense because the Indonesians butchered and ate all of the **Elbe**'s laying hens, terminating the egg supply. But it all seemed to have been patched up when we were there; no one was fretting about it except for the **Elbe**'s rooster. When the **Elbe** is more than half a kilometer from shore, **Ocean East** pulls her along by means of a cable. The tug's movements are controlled from the **Elbe**'s bridge over a radio link. Closer to shore, the **Elbe** drops an anchor and then pulls itself along by winching the line in. She can get more power by using the Harbormaster thruster units mounted on each of her ends. But the main purpose of these thrusters is to provide side propulsion so the barge's movements can be finely controlled.

The nerve center of the **Elbe** is a raised, air-conditioned bridge jammed with the electronic paraphernalia characteristic of modern ships, such as a satellite phone, a fax machine, a plotter, and a Navtex machine to receive meteorological updates. Probably the most important equipment is the differential GPS system that tells the barge's operators exactly where they are with respect to the all-important Route Position List: a series of points provided by the surveyors. Their job is to connect these dots with cable. **Elbe**'s bridge normally sports four different computers all concerned with navigation and station-keeping functions. In addition to this complement, during the Tong Fuk cable lay, Dave Handley was up here with his laptop, taking down data important to FLAG, while the representatives from AT&T and Cable & Wireless were also present with their laptops compiling their own data.

Hey, wait a minute, the hacker tourist says to himself, I thought AT&T was the enemy. What's an AT&T guy doing on the bridge of the **Elbe**, side-by-side with Dave Handley?

The answer is that the telecom business is an unfathomably complicated snarl of relationships. Not only did AT&T (along with KDD) end up with the contract to supply FLAG's cable, it also ended up landing a great deal of the installation work. Not that many companies have what it takes to manage an installation of FLAG's magnitude. AT&T is one of them and Nynex isn't. So it frequently happens at FLAG job sites that AT&T will be serving as the contractor, making the local contacts and organizing the work, while FLAG's presence will be limited to one or two reps whose allegiance is to the investors and whose job it is to make sure it's all done the FLAG way, as opposed to the AT&T way. As with any other construction project from a doghouse on upward, countless decisions must be made on the site, and here they need to be made the way a group of private investors would make them—not the way a club would.

If FLAG's investors spent any time at all looking into the history of the cable-laying business, this topic must have given them a few sleepless nights. The early years of the industry were filled with decision making that can most charitably be described as colorful. In those days, there were no experienced old hands. They just made everything up as they went along, and as often as not, they got it wrong.

Thomson and Whitehouse

As of 1861, some 17,500 kilometers of submarine cable had been laid in various places around the world, of which only about 5,000 kilometers worked. The remaining 12,500 kilometers represented a loss to their investors, and most of these lost investments were long cables such as the ones between Britain and the United States and Britain and India (3,500 and 5,600 kilometers, respectively). Understanding why long cables failed was not a trivial problem; it defeated eminent scientists like Rankine and Siemens and was solved, in the end, only by William Thomson.

In prospect, it probably looked like it was going to be easy. Insulated telegraph wires strung from pole to pole worked just as one might expect, and so, assuming that watertight insulation could be found, similar wires laid under the ocean should work just as well. The insulation was soon found in the form of gutta-percha. Very long gutta-percha-insulated wires were built. They worked fine when laid out on the factory floor and tested. But when immersed in water they worked poorly, if at all.

The problem was that water, unlike air, is an electrical conductor, which is to say that charged particles are free to move around in it. When a pulse of electrons moves down an immersed cable, it repels electrons in the surrounding seawater, creating a positively charged pulse in the water outside. These two charged regions interact with each other in such a way as to smear out the original pulse moving down the wire. The operator at the receiving end sees only a slow upward trend in electrical charge, instead of a crisp jump. If the sending operator transmitted the different pulses—the dots and dashes—too close together, they'd blur as they moved down the wire.

Unfortunately, that's not the only thing happening in that wire. Long cables act as antennae, picking up all kinds of stray currents as the rotation of the Earth, and its revolution around the sun, sweep them across magnetic fields of terrestrial and celestial origin. At the Museum of Submarine Telegraphy in Porthcurno, Cornwall (which we'll visit later), is a graph of the so-called Earth current measured in a cable that ran from there to Harbor Grace, Newfoundland, decades ago. Over a period of some 72 hours, the graph showed a variation in the range of 100 volts. Unfortunately, the amplitude of the telegraph signal was only 70 volts. So the weak, smeared-out pulses making their way down the cable would have been almost impossible to hear above the music of the spheres.

Finally, leakage in the cable's primitive insulation was inevitable. All of these influences, added together, meant that early telegraphers could send anything they wanted into the big wire, but the only thing that showed up at the other end was noise.

These problems were known, but poorly understood, in the mid-1850s when the first transatlantic cable was being planned. They had proved troublesome but manageable in the early cables that bridged short gaps, such as between England and Ireland. No one knew, yet, what would happen in a much longer cable system. The best anyone could do, short of building one, was to make predictions.

The Victorian era was an age of superlatives and larger-than-life characters, and as far as that goes, Dr. Wildman Whitehouse fit right in: what Victoria was to monarchs, Dickens to novelists, Burton to explorers, Robert E. Lee to generals, Dr. Wildman Whitehouse was to assholes. He achieved a level of pure accomplishment in this field that the Alfonse D'Amatos of our time can only dream of. The only 19th-century figure who even comes close to him in this department is Custer. In any case, Dr. Edward Orange Wildman Whitehouse fancied himself something of an expert on electricity. His rival was William Thomson, 10 years younger, a professor of natural philosophy at Glasgow University who was infatuated with Fourier analysis, a new and extremely powerful tool that happened to be perfectly suited to the problem of how to send electrical pulses down long submarine cables.

Wildman Whitehouse predicted that sending bits down long undersea cables was going to be easy (the degradation of the signal would be proportional to the length of the cable) and William Thomson predicted that it was going to be hard (proportional to the length of the cable squared). Naturally, they both ended up working for the same company at the same time.

Whitehouse was a medical doctor, hence working in the wrong field, and probably trailed Thomson by a good 50 or 100 IQ points. But that didn't stop Whitehouse. In 1856, he published a paper stating that Thomson's theories concerning the proposed transatlantic cable were balderdash. The two men got into a public argument, which became extremely important in 1858 when the Atlantic Telegraph Company laid such a cable from Ireland to Newfoundland: a copper core sheathed in gutta-percha and wrapped in iron wires.

This cable was, to put it mildly, a bad idea, given the state of cable science and technology at the time. The notion of copper as a conductor for electricity, as opposed to a downspout material, was still extraordinary, and it was impossible to obtain the metal in anything like a pure form. The cable was slapped together so shoddily that in some places the core could be seen poking out through its gutta-percha insulation even before it was loaded onto the cable-laying ship. But venture capitalists back then were a more rugged—not to say crazy—breed, and there can be no better evidence than that they let Wildman Whitehouse stay on as the Atlantic Telegraph Company's chief electrician long after his deficiencies had become conspicuous.

The physical process of building and laying the cable makes for a wild tale in and of itself. But to do it justice, I would have to double the length of this already herniated article. Let's just say that after lots of excitement, they put a cable in place between Ireland and Newfoundland. But for all of the reasons mentioned earlier, it hardly worked at all. Queen Victoria managed to send President Buchanan a celebratory message, but it took a whole day to send it. On a good day, the cable could carry something like one word per minute. This fact was generally hushed up, but the important people knew about it—so the pressure was on Wildman Whitehouse, whose theories were blatantly contradicted by the facts.

Whitehouse convinced himself that the solution to their troubles was brute force—send the message at extremely high voltages. To that end, he invented and patented a set of 5-foot-long induction coils capable of ramming 2,000 volts into the cable. When he hooked them up to the Ireland end of the system, he soon managed to blast a hole through the gutta-percha somewhere between there and Newfoundland, turning the entire system into useless junk.

Long before this, William Thomson had figured out, by dint of Fourier analysis, that incoming bits could be detected much faster by a more sensitive instrument. The problem was that instruments in those days had to work by physically moving things around, for example, by closing an electromagnetic relay that would sound a buzzer. Moving things around requires power, and the bits on a working transatlantic cable embodied very little power. It was difficult to make a physical object small enough to be susceptible to such ghostly traces of current.

Thomson's solution (actually, the first of several solutions) was the mirror galvanometer, which incorporated a tiny fleck of reflective material that would twist back and forth in the magnetic field created by the current in the wire. A beam of light reflecting from the fleck would swing back and forth like a searchlight, making a dim spot on a strip of white paper. An observer with good eyesight sitting in a darkened room could tell which way the current was flowing by watching which way the spot moved. Current flowing in one direction signified a Morse code dot, in the other a dash. In fact, the information that had been transmitted down the cable in the brief few weeks before Wildman Whitehouse burned it to a crisp had been detected using Thomson's mirror galvanometer—though Whitehouse denied it.

After the literal burnout of the first transatlantic cable, Wildman Whitehouse and Professor Thomson were grilled by a committee of eminent Victorians who were seriously pissed off at Whitehouse and enthralled with Thomson, even before they heard any testimony—and they heard a lot of testimony.
Whitehouse disappeared into ignominy. Thomson ended up

being knighted and later elevated to a baron by Queen Victoria. He became Lord Kelvin and eventually got an important unit of measurement, an even more important law of physics, and a refrigerator named after him.

Eight years after Whitehouse fried the first, a second transatlantic cable was built to Lord Kelvin's specifications with his patented mirror galvanometers at either end of it. He bought a 126-ton schooner yacht with the stupendous amount of money he made from his numerous cable-related patents, turned the ship into a floating luxury palace and laboratory for the invention of even more fantastically lucrative patents. He then spent the rest of his life tooling around the British Isles, Bay of Biscay, and western Mediterranean, frequently hosting Dukes and continental savants who all commented on the nerd-lord's tendency to stop in the middle of polite conversation to scrawl out long skeins of equations on whatever piece of paper happened to be handy.

Kelvin went on to design and patent other devices for extracting bits from the ends of cables, and other engineers went to work on the problem, too. By the 1920s, the chore of translating electrical pulses into letters had been largely automated. Now, of course, humans are completely out of the loop.

The number of people working in cable landing stations is probably about the same as it was in Kelvin's day. But now they are merely caretakers for machines that process bits about as fast as a billion telegraphers working in parallel.

The Hacker Tourist travels to the Land of the Rising Sun.

Technological wonders of modern cable stations. Why Ugandans could not place telephone calls to Seattle. Trawlers, tickler chains, teredo worms, and other hazards to undersea cables. The immense financial stakes involved—why cable owners do not care for the company of fishermen,and vice versa.

35° 17.690' N, 139° 46.328' EKDD Cable Landing

Station, Ninomiya, Japan

Whether they are in Thailand, Egypt, or Japan, modern cable landing stations have much in common with each other. Shortly after touching down in Tokyo, we were standing in KDD's landing station in Ninomiya, Japan. I'll describe it to you.

A surprising amount of space in the station is devoted to electrical gear. The station must not lose power, so there are two separate, redundant emergency generators. There is also likely to be a transformer to supply power to the cable system. We think of optical fibers as delicate strands consuming negligible power, but all of those repeaters, spaced every few dozen kilometers across an ocean, end up consuming a lot of juice: for a big transoceanic cable, one or two amperes at 7,000 or so volts, for a total of something like 10,000 watts. The equipment handling that power makes a hum you can feel in your bones, kicking the power out not along wires but solid copper bars suspended from the ceiling, with occasional sections of massive braided metal ribbon so they won't snap in an earthquake.

The emergency generators are hooked into a battery farm that fills a room. The batteries are constantly trickle-charged and exist simply to provide power during an emergency—after the regular power goes out but before the generators kick in. Most of the equipment in the cable station is computer gear that demands a stable temperature, so there are two separate, redundant air-conditioning plants feeding into a big system of ventilation ducts. The equipment must not get dirty or get fried by sparks from the fingers of hacker tourists, so you leave your shoes by the door and slip into plastic antistatic flip-flops. The equipment must not get smashed up in earthquakes, so the building is built like a brick shithouse.

The station is no more than a few hundred meters from a beach. Sandy beaches in out-of-the-way areas are preferred. The cable comes in under the sand until it hits a beach manhole, where it continues through underground ducts until it comes up out of the floor of the cable station into a small, well-secured room. The cable is attached to something big and strong, such as a massive steel grid bolted into the wall. Early cable technicians were sometimes startled to see their cables suddenly jerk loose from their moorings inside the station—yanking the guts out of expensive pieces of equipment—and disappear in the direction of the ocean, where a passing ship had snagged them.

From holes in the floor, the cables pass up into boxes where all the armor and insulation are stripped away from them and where the tubular power lead surrounding the core is connected to the electrical service (7,500 volts in the case of FLAG) that powers the repeaters out in the middle of the ocean. Its innards then con-tinue, typically in some kind of overhead wiring plenum (a miniature catwalk suspended from the ceiling) into the Big Room Full of Expensive Stuff.

The Big Room Full of Expensive Stuff is at least 25 meters on a side and commonly has a floor made of removable, perforated plates covering plenums through which wires can be routed, an overhead grid of open plenums from which wires descend like jungle vines, or both. Most of the room is occupied by equipment racks arranged in parallel rows (think of the stacks at a big library). The racks are tall, well over most people's heads, and their insides are concealed and protected by face plates bearing corporate logos: AT&T, Alcatel, Fujitsu. In the case of an optical cable like FLAG, they contain the Light Terminal: the gear that converts the 1,558-nanometer signal lasers coming down the fiber strands into digits within an electrical circuit, and vice versa. The Light Terminal is contained within a couple of racks that, taken together, are about the size of a refrigerator.

All the other racks of gear filling the room cope with the unfathomable hassles associated with trying to funnel that many bits into and out of the fiber. In the end, that gear is, of course, connected to the local telecommunications system in some way. Hence one commonly sees microwave relay towers on top of these buildings and lots of manholes in the streets around them. One does not, however, see a lot of employees, because for the most part this equipment runs itself. Every single circuit board in every slot of every level of every rack in the whole place has a pair of copper wires coming out of it to send an alarm signal in the event that the board fails. Like tiny rivulets joining together into a mighty river, these come together into bundles as thick as your leg that snake beneath the floor plates to an alarm center where they are patched into beautiful rounded clear plastic cases enclosing grids of interconnect pins. From here they are tied into communications lines that run all the way to Tokyo so that everything on the premises can be monitored remotely during nights and weekends. Ninomiya is staffed with nine employees and Miura, FLAG's other Japanese landing point, only one.

With one notable exception, the hacker tourist sees no particular evidence that any of this has the slightest thing to do with communications. It might as well be the computer room at a big university or insurance company. The one exception is a telephone handset hanging on a hook on one of the equipment racks. The handset is there, but there's no keypad. Above it is a sign bearing the name of a city far, far away. "Ha, ha!" I said, the first time I saw one of these, "that's for talking to the guy in California, right?" To my embarrassment, my tour guides nodded yes. Each cable system has something called the **order wire**, which enables the technicians at opposite ends of the cable to talk to each other. At a major landing station you will see several order wires labeled with the names of exotic-sounding cities on the opposite side of the nearest large body of water.

That is the bare minimum that you will see at any cable station. At Ninomiya you see a bit more, and therein lies something of a tale.

Ninomiya is by far the oldest of KDD's seven cable landing stations, having been built in 1964 to land TPC-1, which connected Japan to Guam and hence to the United States. Unlike many of FLAG's other landing sites, which are still torn up by backhoe tracks, it is surrounded by perfectly maintained gardens marred only by towering gray steel poles with big red lights on them aimed out toward the sea in an attempt to dissuade mariners from dropping anchor anywhere nearby. Ninomiya served as a training ground for Japanese cable talent. Some of the people who learned the trade there are among the top executives in KDD's hierarchy today.

During the 1980s, when Americans started to get freaked out about Japan again, we heard a great deal about Japanese corporations' patient, long-term approach to R&D and how vastly superior it was to American companies' stupid, short-term approach. Since American news media are at least as stupid and short-term as the big corporations they like to bitch about, we have heard very little follow-up to such stories in recent years, which is kind of disappointing because I was sort of wondering how it was all going to turn out. But now the formerly long-term is about to come due.

By the beginning of the 1980s, the generation of cable-savvy KDD men who had cut their teeth at Ninomiya had reached the level where they could begin diverting corporate resources into R&D programs. Tohru Ohta, who today is the executive vice president of KDD, managed to pry some money loose and get it into the hands of a protégé, Dr. Yasuhiko Niiro, who launched one of those vaunted far-sighted Japanese R&D programs at Ninomiya. The terminal building for TPC-1, which had been the center of the Japanese international telecommunications network in 1964, was relegated to a laboratory for Niiro. The goal was to make KDD a player in the optical-fiber submarine cable manufacturing business.

Such a move was not without controversy in the senior ranks of KDD, who had devoted themselves to a very different corporate mission. In 1949, when Japan was still being run by Douglas MacArthur and the country was trying to dig out from the rubble of the war, Nippon Telephone & Telegraph (NT&T) split off its international department into a new company called Kokusai Denshin Denwa Co., Ltd. (KDD), which means International Telegraph & Telephone. KDD was much smaller and more focused than NT&T, and this was for a reason: Japan's international communications system was a shambles, and nothing was more important to the country's economic recovery than that it be rehabilitated as quickly as possible. The hope was that KDD would be more nimble and agile than its lumbering parent and get the job done faster.

This strategy seems to have more or less worked. Obviously, Japan has succeeded in the world of international business. It is connected to the United States by numerous transpacific cables; lines to the outside world are plentiful. Of course, since KDD enjoyed monopoly status for a long time, the fact that these lines are plentiful has never led to their being cheap. Still, the system worked. Like much else that worked in Japan's postwar economy, it succeeded, in those early years, precisely insofar as it worked hand-in-glove with American companies and institutions. AT&T, in other words.

Unlike the United States or France or Great Britain, Japan was never much of a player in the submarine cable business back in the prewar days, and so Ohta's and Niiro's notion of going into head-to-head competition against AT&T, its postwar sugar daddy, might have seemed audacious. KDD had customarily been so close to AT&T that many Japanese mocked it cruelly. AT&T is the sumo champion, they said, and KDD is its **koshi-ginchaku**, its belt-holding assistant. The word literally means **waist purse** but seems to have rude connotations along the lines of **jockstrap carrier**.

Against all of that, the only thing that Ohta and Niiro had to go on was the fact that their idea was a really, really good one. Building cables is just the kind of thing that Japanese industry is good at: a highly advanced form of manufacturing that requires the very best quality control. Cables and repeaters have to work for at least 25 years under some really unpleasant conditions.

KDD Submarine Cable Systems (KDD-SCS) built its first optical fiber submarine cable system, TPC-3, in 1989 and will soon have more than 100,000 kilometers of cable in service worldwide. It designs and holds the patents on the terminal equipment that we saw at Ninomiya, though the equipment itself is manufactured by electronics giants like Toshiba and NEC. KDD-SCS is building some of the cable and repeaters that make up FLAG, and AT&T-SSI is building the rest. A problem has already surfaced in the AT&T repeaters—they switched to a different soldering technique which turns out to be not such a good idea. Eleven of the repeaters that AT&T made for FLAG have this problem, and all of them are lying on the bottom of oceans with bits running through them—for now. FLAG and AT&T are still studying this problem and trying to decide how to resolve it. Still, everyone in the cable business knows what happened —it has to be considered a major win for KDD-SCS.

So when KDD threw some of its resources into one of those famous far-sighted long-range Japanese R&D programs, it paid off beautifully. In the field of submarine cable systems, the lowly assistant has taught the sumo champion a lesson and sent him reeling back—not quite out of the ring, but certainly enough to get his attention. How, you might ask, is the rest of KDD doing?

The answer is that, like most other PTTs, it's showing its age. Even the tactful Japanese are willing to admit that they have performed poorly in the world of international telecommunications compared to other countries. Non-Japanese will tell you the same thing more enthusiastically.

The telco deregulation wars have begun in Japan as they have almost everywhere else, and KDD now has competitors in the form of International Digital Communications Inc. (IDC), which owns the Miura station, the other FLAG landing spot. In order to succeed in this competition, KDD needs to invest a lot of money, but the very smallness that made it such a good idea in 1949 puts it at a disadvantage when large amounts of capital are needed.

Just as Ninomiya is a generic cable landing, so KDD is something of a generic PTT, facing many of the same troubles that others do. For example: the Japanese telecommunications ministry continues to set rates at an artificially high level. At first blush, this would seem to help KDD by making it much more difficult for upstarts like IDC to compete with them. But in fact it has opened the door to an unexpected form of competition: callback.

Callback and **Kallback** are registered trademarks of Seattle-based International Telcom Ltd. (ITL), but, like **band-aid** and **kleenex,** tend to be used in a generic way by people overseas. The callback concept is based on the fact that it's much cheaper to call Japan from the US than it is to call the US from Japan. Subscribers to a callback service are given a phone number in the US. When they want to make a call, they dial that number, wait for it to ring once, and then hang up so they won't be charged for the call. In the jargon of the callback world, this is the **trigger call**. A system in the US then calls them back, giving them a cheap international line, and once that is accomplished, it's an easy matter to shunt the call elsewhere: to a number in the States or in any other country in the world.

Any phone call made between two countries is subject to a so-called settlement charge, which is assessed on a per-minute basis. The amount of the settlement charged is fixed by an agreement between the two countries' PTTs and generally provides a barometer of their relative size and power. So, for example, when working out the deal with Denmark, Pakistan might say, "Hey, Danes are rich, and we don't really care whether they call us or not, and they have no particular leverage over us—so POW!" and insist on a high settlement charge—say $4 per minute. But when negotiating against AT&T, Pakistan might agree to a lower settlement charge—say $1 per minute.

Settlement charges have long been a major source of foreign exchange for developing countries' PTTs and hence for their governments and any crooked officials who may be dipping into the money stream. In some underdeveloped nations, they have been the major—verging on the only—source of such income. But not for long.

Nowadays, a Dane who makes lot of international calls will subscribe to a service such as ITL's Kallback. He makes a trigger call to Kallback's computer in Seattle, which, since it is an incomplete call, costs him nothing. The computer phones him back within a few seconds. He then punches in the number he wants to call in Pakistan, and the computer in Seattle places the call for him and makes the connection. Since Pakistan's PTT has no way to know that the call originates in Denmark, it assesses the lower AT&T settlement charge. The total settlement charge ends up being much less than what the Dane would have paid if he'd dialed Pakistan directly. In other words, two calls from the US, one to point A and one to point B, are cheaper than one direct call from point A to point B.

KDD, like many other PTTs around the world, has tried to crack down on callback services by compiling lists of the callback numbers and blocking calls to those numbers. When I talked to Eric Doescher, ITL's director of marketing, I expected him to be outraged about such attacks. But it soon became evident that if he ever felt that way, he long ago got over it and now views all such efforts with jaded amusement. "In Uganda," he said, "the PTT blocked all calls to the 206 area code. So we issued numbers from different area codes. In Saudi Arabia, they disabled touch-tones upon connection so our users were unable to place calls when the callback arrived—so we instituted a sophisticated voice recognition system—customer service reps who listened to our customers speaking the number and keyed it into the system." In Canada, a bizarre situation developed in which calls from the Yukon and Northwest Territories to the big southeastern cities like Ottawa and Toronto were actually cheaper—by a factor of three—when routed through Seattle than when dialed directly. In response to the flood of Kallback traffic, Canada's Northern Telecom had human operators monitor phone calls, listening for the distinctive pattern of a trigger call: one ring followed by a hang-up. They then blocked calls to those numbers. So ITL substituted a busy signal for the ringing sound. Northern Telecom, unwilling to block calls to every phone in the US that was ever busy, was checkmated.

In most countries, callback services inhabit a gray area. Saudi Arabia and Kenya occasionally run ads reminding their people that callback is illegal, but they don't try to enforce the law. China has better luck with enforcement because of its system of informants, but it doesn't bother Western businesspeople, who are the primary users. Singapore has legalized them on the condition that they don't advertise. In Italy, the market is so open that ITL is about to market a debit card that enables people to use the service from any pay phone.

So settlement charges have backfired on the telcos of many countries. Originally created to coddle these local monopolies, they've now become a hazard to their existence.

KDD carries all the baggage of an old monopoly: it works in conjunction with a notoriously gray and moribund government agency, it still has the bad customer-service attitude that is typical of monopolies, and it has the whole range of monopoly PR troubles too. Any competitive actions that it takes tend to be construed as part of a sinister world domination plot. So KDD has managed to get the worst of both worlds: it is viewed both as a big sinister monopoly and as a cringing sidekick to the even bigger and more sinister AT&T.

Michio Kuroda is a KDD executive who negotiates deals relating to submarine cables. He tells of a friend of his, a KDD employee who went to the United States two decades ago to study at a university and went around proudly announcing to his new American acquaintances that he worked for a monopoly. Finally, some kind soul took him aside and gently broke the news to him that, in America, monopoly was an ugly word.

Now, 20 years later, Kuroda claims that KDD has come around; it agrees now that monopoly is an ugly word. KDD's detractors will say that this is self-serving, but it rings true to this reporter. It seems clear that a decision has been made at the highest levels of KDD that it's time to stop looking backward and start to compete. As KDD is demonstrating, fat payrolls can be trimmed. Capital can be raised. Customer service can be improved, prices cut, bad PR mended. The biggest challenge that KDD faces now may stem from a mistake that it made several years ago: it decided not to land FLAG.

35° 11.535′ N, 139° 36.995′ EIDC Cable Landing Station, Miura, Japan

The Miura station of IDC, or International Digital Communications Inc., looks a good deal like KDD's Ninomiya station on the inside, except that its equipment is made by Fujitsu instead of KDD-SCS. At first approximation, you might think of IDC as being the MCI of Japan. Originally it specialized in data transmission, but now that deregulation has arrived it is also a long-distance carrier. This, by the way, is a common pattern in Asian countries where deregulation is looming: new companies will try to kick out a niche for themselves in data or cellular markets and hold on by their toenails until the vast long-distance market opens up to them. Anyone in Japan can dial an international call over IDC's network by dialing the prefix 0061 instead of 001 for KDD. The numerical prefixes of various competing long-distance companies are slapped up all over Tokyo on signs and across rear windows of taxicabs in a desperate attempt to get a tiny edge in mindshare.

Miura's outer surroundings are quite different from Ninomiya's. Ninomiya is on a bluff in the middle of a town, and the beach below it is a narrow strip of sand chockablock with giant concrete tetrapods, looking like vastly magnified skeletons of plankton and intended to keep waves from washing up onto the busy coastal highway that runs between the beach and the station. Miura, by contrast, is a resort area with a wide beach lined with seasonal restaurants. When we were there we even saw a few surfers, hunting for puny waves under a relentless rain, looking miserable in black wetsuits. The beach gives way to intensively cultivated farmland.

Miura is the Japan end of NPC, the Northern Pacific Cable, which links it directly to Pacific City, Oregon, with 8,380 kilometers of second-generation optical fiber (it carries three fiber pairs, each of which handles 420 Mbps). Miura also lands APC, the Asia-Pacific Cable, which links it to Hong Kong and Singapore, and by means of a short cable under Tokyo Bay it is connected to KDD's Chikura station, which is a major nexus for transpacific and East Asian cables.

When FLAG first approached KDD with its wild scheme to build a privately financed cable from England to Japan, there were plenty of reasons for KDD to turn it down. The US Commerce Department was pressuring KDD to accept FLAG, but AT&T was against it. KDD was now caught between **two** sumo wrestlers trying to push it opposite ways. Also in the crowded ring was Japan's telecommunications ministry, which maintained that plenty of bandwidth already existed and that FLAG would somehow create a glut on the market. Again, this attitude is probably difficult for the hacker tourist or any other Net user to comprehend, but it seems to be ubiquitous among telecrats.

Finally, KDD saw advantages in the old business model in which cables are backed, and owned, by carriers—it likes the idea of owning a cable and reaping profits from it rather than allowing a bunch of outside investors to make all the money.

For whatever reasons, KDD declined FLAG's invitation, so FLAG made overtures to IDC, which readily agreed to land the cable at its Miura station, where it could be cross-connected with NPC.

A similar scenario played out in Korea, by the way, where Korea Telecom, traditionally a loyal member of the AT&T family, turned FLAG down at first. FLAG approached a competitor named Dacom, and, faced with that threat, Korea Telecom changed its mind and decided to break with AT&T and land FLAG after all. But in Japan, KDD, perhaps displaying more loyalty than was good for it, held the line. Miura became FLAG's Japanese landing station by default—a huge coup for IDC, which could now route calls to virtually anywhere in the world directly from its station.

All of this happened prior to a major FLAG meeting in Singapore in 1992, which those familiar with the project regard as having been a turning point. At this meeting it became clear that FLAG was a serious endeavor, that it really was going to happen. Not long afterward, AT&T decided to adopt an "if you can't beat 'em, join 'em" strategy toward FLAG, which eventually led to it and KDD Submarine Cable Systems getting the contract to build FLAG's cable and repeaters. (AT&T-SSI is supplying 64 percent of the cable and 59 percent of the repeaters, and KDD-SCS is supplying the rest.) This was a big piece of good news for KDD-SCS, the competitive-minded manufacturer, but it put KDD the poky long-distance company in the awkward, perhaps even absurd situation of supplying the hardware for a project that it had originally opposed and that would end up being a cash cow for its toughest competitor.

So KDD changed its mind and began trying to get in on FLAG. Since FLAG was already coming ashore at a station owned by IDC, this meant creating a second landing in Japan, at Ninomiya. In no other country would FLAG have two landings controlled by two different companies. For arcane contractual reasons, this meant that all of the other 50-odd carriers involved in FLAG would have to give unanimous consent to the arrangement, which meant in practice that IDC had veto power. At a ceremony opening a new KDD-SCS factory on Kyushu, executives from KDD and IDC met to discuss the idea. IDC agreed to let KDD in, in exchange for what people on both sides agree were surprisingly reasonable conditions.

At first blush it might seem as though IDC was guilty of valuing harmony and cooperation over the preservation of shareholder value—a common charge leveled against Japanese corporations by grasping and peevish American investors. Perhaps there was some element of this, but the fact is that IDC did have good reasons for wanting FLAG connected to KDD's network. KDD's Ninomiya station is scheduled to be the landing site for TPC-5, a megaproject of the same order of magnitude as FLAG: 25,000 kilometers of third-generation optical fiber cable swinging in a vast loop around the Pacific, connecting Japan with the West Coast of the US. With both FLAG and TPC-5 literally coming into the same room at Ninomiya, it would be possible to build a cross-connect between the two, effectively extending FLAG's reach across the Pacific. This would add a great deal of value to FLAG and hence would be good for IDC.

In any case, the deal fell through because of a strong anti-FLAG faction within KDD that could not tolerate the notion of giving any concessions whatever to IDC. There it stalemated until FLAG managed to cut a deal with China Telecom to run a full-bore 10.6 Gbps spur straight into Shanghai. While China has other undersea cable connections, they are tiny compared with FLAG, which is now set to be the first big cable, as well as the first modern Internet connection, into China.

At this point it became obvious that KDD absolutely had to get in on the FLAG action no matter what the cost, and so it returned to the bargaining table—but this time, IDC, sensing that it had an overpoweringly strong hand, wanted much tougher conditions. Eventually, though, the deal was made, and now jumpsuited workers are preparing rooms at both Ninomiya and Miura to receive the new equipment racks, much like expectant parents wallpapering the nursery. At Ninomiya, an immense cross-connect will be built between

FLAG and TPC-5, and Miura will house a cross-connect between FLAG and the smaller NPC cable.

The two companies will end up on an equal footing as far as FLAG is concerned, but the crucial strategic misstep has already been made by KDD: by letting IDC be the first to land FLAG, it has given its rival a chance to acquire a great deal of experience in the business. It is not unlike the situation that now exists between AT&T, which used to be the only company big and experienced enough to put together a major international cable, and Nynex, which has now managed to get its foot in that particular door and is rapidly gaining the experience and contacts needed to compete with AT&T in the future.

Hazards

Dr. Wildman Whitehouse and his 5-foot-long induction coils were the first hazard to destroy a submarine cable but hardly the last. It sometimes seems as though every force of nature, every flaw in the human character, and every biological organism on the planet is engaged in a competition to see which can sever the most cables. The Museum of Submarine Telegraphy in Porthcurno, England, has a display of wrecked cables bracketed to a slab of wood. Each is labeled with its cause of failure, some of which sound dramatic, some cryptic, some both: trawler maul, spewed core, intermittent disconnection, strained core, teredo worms, crab's nest, perished core, fish bite, even "spliced by Italians." The teredo worm is like a science fiction creature, a bivalve with a rasp-edged shell that it uses like a buzz saw to cut through wood—or through submarine cables. Cable companies learned the hard way, early on, that it likes to eat gutta-percha, and subsequent cables received a helical wrapping of copper tape to stop it.

A modern cable needn't be severed to stop working. More frequently, a fault in the insulation will allow seawater to leak in and reach the copper conductor that carries power to the repeaters. The optical fibers are fine, but the repeater stops working because its power is leaking into the ocean. The interaction of electricity, seawater, and other chemical elements present in the cable can produce hydrogen gas that forces its way down the cable and chemically attacks the fiber or delicate components in the repeaters.

Cable failure can be caused by any number of errors in installation or route selection. Currents, such as those found before the mouths of rivers, are avoided. If the bottom is hard, currents will chafe the cable against it—and currents and hard bottoms frequently go together because currents tend to scour sediments away from the rock. If the cable is laid with insufficient slack, it may become suspended between two ridges, and as the suspended part rocks back and forth, the ridges eventually wear through the insulation. Sand waves move across the bottom of the ocean like dunes across the desert; these can surface a cable, where it may be bruised by passing ships. Anchors are a perennial problem that gets much worse during typhoons, because an anchor that has dropped well away from a cable may be dragged across it as the ship is pushed around by the wind.

In 1870, a new cable was laid between England and France, and Napoleon III used it to send a congratulatory message to Queen Victoria. Hours later, a French fisherman hauled the cable up into his boat, identified it as either the tail of a sea monster or a new species of gold-bearing seaweed, and cut off a chunk to take home. Thus was inaugurated an almost incredibly hostile relationship between the cable industry and fishermen. Almost anyone in the cable business will be glad, even eager, to tell you that since 1870 the intelligence and civic responsibility of fisherman have only degraded. Fishermen, for their part, tend to see everyone in the cable business as hard-hearted bluebloods out to screw the common man.

Most of the fishing-related damage is caused by trawlers, which tow big sacklike nets behind them. Trawlers seem designed for the purpose of damaging submarine cables. Various types of hardware are attached to the nets. In some cases, these are otter boards, which act something like rudders to push the net's mouth open. When bottom fish such as halibut are the target, a massive bar is placed across the front of the net with heavy **tickler chains** dangling from it; these flail against the bottom, stirring up the fish so they will rise up into the maw of the net.

Mere impact can be enough to wreck a cable, if it puts a leak in the insulation. Frequently, though, a net or anchor will snag a cable. If the ship is small and the cable is big, the cable may survive the encounter. There is a type of cable, used up until the advent of optical fiber, called 21-quad, which consists of 21 four-bundle pairs of cable and a coaxial line. It is 15 centimeters in diameter, and a single meter of it weighs 46 kilograms. If a passing ship should happen to catch such a cable with its anchor, it will follow a very simple procedure: abandon it and go buy a new anchor.

But modern cables are much smaller and lighter—a mere 0.85 kg per meter for the unarmored, deep-sea portions of the FLAG cable—and the ships most apt to snag them, trawlers, are getting bigger and more powerful. Now that fishermen have massacred most of the fish in shallower water, they are moving out deeper. Formerly, cable was plowed into the bottom in water shallower than 1,000 meters, which kept it away from the trawlers. Because of recent changes in fishing practices, the figure has been boosted to 2,000 meters. But this means that the old cables are still vulnerable.

When a trawler snags a cable, it will pull it up off the seafloor. How far it gets pulled depends on the weight of the cable, the amount of slack, and the size and horsepower of the ship. Even if the cable is not pulled all the way to the surface, it may get kinked—its minimum bending radius may be violated. If the trawler does succeed in hauling the cable all the way up out of the water, the only way out of the situation, or at least the simplest, is to cut the cable. Dave Handley once did a study of a cable that had been suddenly and mysteriously severed. Hauling up the cut end, he discovered that someone had sliced through it with a cutting torch.

There is also the obvious threat of sabotage by a hostile government, but, surprisingly, this almost never happens. When cypherpunk Doug Barnes was researching his Caribbean project, he spent some time looking into this, because it was exactly the kind of threat he was worried about in the case of a data haven. Somewhat to his own surprise and relief, he concluded that it simply wasn't going to happen. "Cutting a submarine cable," Barnes says, "is like starting a nuclear war. It's easy to do, the results are devastating, and as soon as one country does it, all of the others will retaliate.

"Bert Porter, a Cable & Wireless cable-laying veteran who is now a freelancer, was beachmaster for the Tong Fuk lay. He was on a ship that laid a cable from Hong Kong to Singapore during the late 1960s. Along the way they passed south of Lan Tao Island, and so the view from Tong Fuk Beach is a trip down memory lane for him. "The repeater spacing was about 18 miles," he says, "and so the first repeater went into the water right out there. Then, a few days later, the cable suddenly tested broken." In other words, the shore station in Hong Kong had lost contact with the equipment on board Porter's cable ship. In such cases it's easy to figure out roughly where the break occurred—by measuring the resistance in the cable's conductors—and they knew it had to be somewhere in the vicinity of the first repeater. "So we backtracked, pulling up cable, and when we got right out there," he waves his hand out over the bay, "we discovered that the repeater had simply been chopped out." He holds his hands up parallel, like twin blades. "Apparently the Chinese were curious about our repeaters, so they thought they'd come out and get one."

As the capacity of optical fibers climbs, so does the economic damage caused when the cable is severed. FLAG makes its money by selling capacity to long-distance carriers, who turn around and resell it to end users at rates that are increasingly determined by what the market will bear. If FLAG gets chopped, no calls get through. The carriers' phone calls get routed to FLAG's competitors (other cables or satellites), and FLAG loses the revenue represented by those calls until the cable is repaired. The amount of revenue it loses is a function of how many calls the cable is physically capable of carrying, how close to capacity the cable is running, and what prices the market will bear for calls on the broken cable segment. In other words, a break between Dubai and Bombay might cost FLAG more in revenue loss than a break between Korea and Japan if calls between Dubai and Bombay cost more.

The rule of thumb for calculating revenue loss works like this: for every penny per minute that the long distance market will bear on a particular route, the loss of revenue, should FLAG be severed on that route, is about $3,000 a minute. So if calls on that route are a dime a minute, the damage is $30,000 a minute, and if calls are a dollar a minute, the damage is almost a third of a million dollars for every minute the cable is down. Upcoming advances in fiber bandwidth may push this figure, for some cables, past the million-dollar-a-minute mark.

Clearly, submarine cable repair is a good business to be in. Cable repair ships are standing by in ports all over the world, on 24-hour call, waiting for a break to happen somewhere in their neighborhood. They are called **agreement ships**. Sometimes, when nothing else is going on, they will go out and pull up old abandoned cables. The stated reason for this is that the old cables present a hazard to other ships. However, if you do so much as raise an eyebrow at this explanation, any cable man will be happy to tell you the real reason: whenever a fisherman snags his net on anything—a rock, a wreck, or even a figment of his imagination—he will go out and sue whatever company happens to have a cable in that general vicinity. The cable companies are waiting eagerly for the day when a fisherman goes into court claiming to have snagged his nets on a cable, only to be informed that the cable was pulled up by an agreement ship years before.

In which the Hacker Tourist delights in Cairo, the Mother of the World. Alexandria, the former Hacker Headquarters of the planet.

The lighthouse, the libraries, and other haunts of ancient nerds and geeks. Profound significanceof intersections. Travels on the Desert Road. Libya's contact with the outside world rudely severed—then restored! Engineer Musalamand his planetary information nexus. The vitally important concept of Slack

31° 12.841′ N, 29° 53.169′ ESite of the Pharos lighthouse, Alexandria, Egypt

Having stood on the beach of Miura watching those miserable-but-plucky Japanese surfers, the hacker tourist had reached FLAG's easternmost extreme, and there was nothing to do except turn around and head west. Next stop:

Egypt.

No visit to Egypt is complete without a stop in Cairo, but that city, the pinnacle of every normal tourist's traveling career, is strangely empty from a hacker tourist point of view. Its prime attraction, of course, is the pyramids. We visited them at five in the morning during a long and ultimately futile wait for the Egyptian military to give us permission to rendezvous with FLAG's cable-laying ship in the Gulf of Suez. To the hacker, the most interesting thing about the Pyramids is their business plan, which is the simplest and most effective ever devised:

(1) Put a rock on top of another rock.
(2) Repeat (1) until gawkers arrive.
(3) Separate them from their valuables by all conceivable means.

By contrast, normal tourist guidebooks have nothing good to say about Alexandria; it's as if the writers got so tired of marveling at Cairo and Upper Egypt that they had to vent their spleen somewhere. Though a town was here in ancient times, Alexandria per se was founded in 332 BC by Alexander the Great, which makes it a brand-new city by Egyptian standards. There is almost no really old stuff in Alexandria at all, but the mere memory of the landmarks that were here in its heyday suffice to make it much more important than Cairo from the weirdly distorted viewpoint of the hacker tourist. These landmarks are, or were, the lighthouse and the libraries.

The lighthouse was built on the nearby island of Pharos. Neither the building nor even the island exists any more. Pharos was eventually joined to the mainland by a causeway, which fattened out into a peninsula and became a minuscule bump on the scalp of Africa. The lighthouse was an immense structure, at some 120 meters the tallest building in the world for many centuries, and contained as many as 300 rooms. Somewhere in its upper stories a fire burned all night long, and its light was reflected out across the Mediterranean by some kind of rotating mirror or prism. This was a fine bit of ancient hacking in and of itself, but according to legend, the optics also had magnifying properties, so that observers peering through it during the daytime could see ships too distant to be perceived by the naked eye.

According to legend, this feature made Alexandria immune to naval assault as long as the lighthouse remained standing. According to another yarn, a Byzantine emperor spread a rumor that the treasure of Alexander the Great had been hidden within the lighthouse's foundation, and the unbelievably fatuous local caliph tore up the works looking for it, putting Pharos out of commission and leading to a military defeat by the Byzantine Empire.

Some combination or other of gullible caliphs, poor maintenance, and earthquakes eventually did fell the lighthouse. Evidently it toppled right into the Mediterranean. The bottom of the sea directly before its foundations is still littered with priceless artifacts, which are being catalogued and hauled out by French archaeologists using differential GPS to plot their findings. They work in the shadow of a nondescript fortress built on the site by a later sultan, Qait Bey, who pragmatically used a few chunks of lighthouse granite to beef up the walls—just another splinter under the fingernails of the historical preservation crowd.

You can go to the fortress of Qait Bey now and stare out over the ocean and get much the same view that the builders of the lighthouse enjoyed. They must have been able to see all kinds of weirdness coming over the horizon from Europe and western Asia. The Mediterranean may look small on a world map, but from Pharos its horizon seems just as infinite as the Pacific seen from Miura. Back then, knowing how much of the human world was around the Mediterranean, the horizon must have seemed that much more vast, threatening, and exciting to the Alexandrians.

Building the lighthouse with its magic lens was a way of enhancing the city's natural capability for looking to the north, which made it into a world capital for many centuries. It's when a society plunders its ability to look over the horizon and into the future in order to get short-term gain—sometimes illusory gain—that it begins a long slide nearly impossible to reverse.

The collapse of the lighthouse must have been astonishing, like watching the World Trade Center fall over. But it took only a few seconds, and if you were looking the other way when it happened, you might have missed it entirely—you'd see nothing but blue breakers rolling in from the Mediterranean, hiding a field of ruins, quickly forgotten.

31° 11.738′ N, 29° 54.108′ EIntersection of El Horreya and El Nabi Daniel, Alexandria, Egypt

Alexandria is most famous for having been the site of the ancient library. This was actually two or more different libraries. The first one dates back to the city's early Ptolemaic rulers, who were Macedonians, not Egyptians. It was modeled after the Lyceum of Aristotle, who, between other gigs, tutored Alexander the Great. Back in the days when people moved to information, instead of vice versa, this library attracted most of the most famous smart people in the world: the ultimate hacker, Archimedes; the father of geometry, Euclid; Eratosthenes, who was the first person to calculate the circumference of the earth, by looking at the way the sun shone down wells at Alexandria and Aswan. He also ran the library for a while and took the job seriously enough that when he started to go blind in his old age, he starved himself to death. In any event, this library was burned out by the Romans when they were adding Egypt to their empire. Or maybe it wasn't. It's inherently difficult to get reliable information about an event that consisted of the destruction of all recorded information.

The second library was called the Library of Cleopatra and was built around a couple of hundred thousand manuscripts that were given to her by Marc Antony in what was either a magnificent gesture of romantic love or a shrewd political maneuver. Marc Antony suffered from what we would today call "poor impulse control," so the former explanation is more likely. This library was wiped out by Christians in AD 391. Depending on which version of events you read, its life span may have overlapped with that of the first library for a few years, a few decades, or not at all.

Whether or not the two libraries ever existed at the same time, the fact remains that between about 300 BC and AD 400, Alexandria was by far the world capital of high-quality information. It must have had much in common with the MIT campus or Stanford in Palo Alto of more recent times: lots of hairy smart guys converging from all over the world to tinker with the lighthouse or to engage in pursuits that must have been totally incomprehensible to the locals, such as staring down wells at high noon and raving about the diameter of the earth.

The main reason that writers of tourist guidebooks are so cheesed off at Alexandria is that no vestige of the first library remains—not even a plaque stating "The Library of Alexandria was here." If you want to visit the site, you have to do a bit of straightforward detective work. Ancient Alexandria was laid out on a neat, regular grid pattern—just the kind of thing you would expect of a place populated by people like Euclid. The main east-west street was called the Canopic Way, and the main north-south street, running from the waterfront toward the Sahara Desert, was called the Street of the Soma. The library is thought to have stood just south of their intersection.

Though no buildings of that era remain, the streets still do, and so does their intersection. Currently, the Canopic Way is called El Horreya Avenue, and the Soma is called El Nabi Daniel Street, though if you don't hurry, they may be called something else when you arrive.

We stayed at the Cecil Hotel, where Nabi Daniel hits the waterfront. The Cecil is one of those British imperial-era hotels fraught with romance and history, sort of like the entire J. Peterman catalog rolled into one building. British Intelligence was headquartered there during the war, and there the Battle of El Alamein was planned.

Living as they do, however, in a country choked with old stuff, the Egyptians have adopted a philosophy toward architecture that is best summed up by the phrase: "What have you done for me lately?" From this point of view, the Cecil is just another old building, and it's not even particularly old. As if to emphasize this, the side of the hotel where we stayed was covered with a rude scaffolding (sticks lashed together with hemp) aswarm with workers armed with sledgehammers, crowbars, chisels, and the like, who spent all day, every day, bellowing cheerfully at each other (demolition workers are the jolliest men in every country), bashing huge chunks of masonry off the top floor and simply dropping them—occasionally crushing an air conditioner on some guest's balcony. It was a useful reminder that Egyptians feel no great compulsion to tailor their cities to the specifications of guidebook writers.

This fact can be further driven home by walking south on Nabi Daniel and looking for the site of the Library of Alexandria. It is now occupied by office buildings probably not more than 100, nor less than 50, years old. Their openings are covered with roll-up steel doors, and their walls decorated with faded signs. One of them advertises courses in DOS, Lotus, dBase, COBOL, and others. Not far away is a movie theater showing **Forbidden Arsenal: In the Line of Duty 6**, starring Cynthia Khan.

The largest and nicest building in the area is used by an insurance company and surrounded by an iron fence. The narrow sidewalk out front is blocked by a few street vendors who have set up their wares in such a way as to force pedestrians out into the street. One of them is selling pictures of adorable kittens tangled up in yarn, and another is peddling used books. This is the closest thing to a library that remains here, so I spent a while examining his wares: a promising volume called **Bit by Bit** turned out to be an English primer. There were quite a few medical textbooks, as if a doctor had just passed away, and Agatha Christie and Mickey Mouse books presumably left behind by tourists. The closest thing I saw to a classic was a worn-out copy of **Oliver Twist**.

31° 10.916′ N29° 53.784′ EPompey's Pillar

The site of Cleopatra's library, precisely 1 mile away by my GPS, is viewed with cautious approval by guidebook writers because it is an actual ruin with a wall around it, a ticket booth, old stuff, and guides. It is right next to an active Muslim cemetery, so it is difficult to reach the place without excusing your way past crowds of women in voluminous black garments, wailing and sobbing heartrendingly, which all goes to make the Western tourist feel like even more of a penis than usual.

The site used to be the city's acropolis. It is a rounded hill of extremely modest altitude with a huge granite pillar on the top. To quote Shelley's "Ozymandias": "Nothing beside remains." A few sphinxes are scattered around the place, but they were obviously dragged in to give tourists something to look at. Several brutally impoverished gray concrete apartment buildings loom up on the other side of the wall, festooned with washing, crammed with children who entertain themselves by raining catcalls down upon the few tourists who straggle out this far. The granite pillar honors the Roman emperor Diocletian, who was a very bad emperor, a major Christian-killer, but who gave Alexandria a big tax break. The citizenry, apparently just as dimwitted as modern day Americans, decided that he was a great guy and erected this pillar. Originally there was a statue of Diocletian himself on the top, riding a horse, which is why the Egyptians call it, in Arabic, **The man on horseback**. The statue is gone now, which makes this a completely mystifying name. Westerners call it **Pompey's Pillar** because that's the moniker the clueless Crusaders slapped on it; of course, it has absolutely nothing to do with Pompey.

The hacker tourist does not bother with the pillar but rather with what is underneath it: a network of artificial caves, carved into the sandstone, resembling nothing so much as a D & D player's first dungeon. Because it's a hill and this is Egypt, the caverns are nice and dry and (with a little baksheesh in the right hands) can be well lit too—electrical conduit has been run in and light fixtures bolted to the ceiling. The walls of these caves have niches that are just the right size and shape to contain piles of scrolls, so this is thought to be the site of the Library of Cleopatra. This complex was called the Sarapeum, or Temple of Sarapis, who was a conflation of Osiris and Apis admired by the locals and loathed by monotheists, which explains why the whole complex was sacked and burned by Christians in 391.

It is all rather discouraging, when you use your imagination (which you must do constantly in Alexandria) and think of the brilliance that was here for a while. As convenient as it is for information to come to us, libraries do have a valuable side effect: they force all of the smart people to come together in one place where they can interact with one another. When the information goes up in flames, those people go their separate ways. The synergy that joined them —that created the lighthouse, for example—dies. The world loses something.

So the second library is some holes in a wall, and the first is an intersection. Holes and intersections are both absences, empty places, disappointing to tourists of both the regular and the hacker variety. But one can argue that the intersection's continued presence is arguably more interesting than some old pile that has been walled off and embalmed by a historical society. How can an intersection remain in one place for 2,500 years? Simply, both the roads that run through it must remain open and active. The intersection will cease to exist if sand drifts across it because it's never used, or if someone puts up a building there. In Egypt, where yesterday's wonders of the world are today's building materials, nothing is more obvious than that people have been avidly putting up buildings everywhere they possibly can for 5,000 years, so it is remarkable that no such thing has happened here. It means that every time some opportunist has gone out and tried to dig up the street or to start putting up a wall, he has been flattened by traffic, arrested by cops, chased away by outraged donkey-cart drivers, or otherwise put out of action. The existence of this intersection is proof that a certain pattern of human activity has endured in this exact place for 2,500 years.

When the hacker tourist has tired of contemplating the profound significance of intersections (which, frankly, doesn't take very long) he must turn his attention to—you guessed it—cable routes. This turns out to be a much richer vein.

30° 58.319' N, 29° 49.531' EAlexandria Tollbooth, the Desert Road, Sahara Desert, Egypt

As we speed across the Saharan night, the topic of conversation turns to Hong Kong. Our Egyptian driver, relaxed and content after stopping at a roadside rest area for a hubbly-bubbly session (smoking sweetened tobacco in a Middle Eastern bong), smacks the steering wheel gleefully. "Ha, ha, ha!" he roars. "Miserable Hong Kong people!"

Alexandria and Cairo are joined by two separate, roughly parallel highways called the Desert Road and the Agricultural Road. The latter runs through cultivated parts of the Nile Delta. The Desert Road is a rather new, four-lane highway with a tollbooth at each end—tollbooths in the middle not being necessary, because if you get off in the middle you will die. It is lined for its entire length with billboards advertising tires, sunglasses, tires, tires, tires, bottled water, sunglasses, tires, and tires.

Perhaps because it is supported by tolls, the Desert Highway is a first-rate road all the way. This means not merely that the pavement is good but also that it has a system of ducts and manholes buried under its median strip, so that anyone wishing to run a cable from one end of the highway to the other—tollbooth to tollbooth—need only obtain a "permit" and ream out the ducts a little. Or at least that's what the Egyptians say. The Lan Tao Island crowd, who are quite discriminating when it comes to ducts and who share an abhorrence of all things Egyptian, claim that cheap PVC pipe was used and that the whole system is a tangled mess.

They would both agree, however, that beyond the tollbooths the duct situation is worse. The Alexandria Tollbooth is some 37 kilometers outside of the city center; you get there by driving along a free highway that has no ducts at all.

This problem is being remedied by FLAG, which has struck a deal with ARENTO (Arab Republic of Egypt National Telecommunications Organization—the PTT) that is roughly analogous to the one it made with the Communications Authority of Thailand. FLAG has no choice but to go overland across Egypt, just as in Thailand. The reasons for doing so here are entirely different, though.

By a freak of geography and global politics, Egypt possesses the same sort of choke point on Europe-to-Asia telecommunications as the Suez canal gives it in the shipping industry. Anyone who wants to run a cable from Europe to East Asia has severely limited choices. You can go south around Africa, but it's much too far. You can go overland across all of Russia, as U S West has recently talked about doing, but if even a 170-kilometers terrestrial route across Thailand gets your customers fumbling for their smelling salts, what will they say about one all the way across Russia? You could attempt a shorter terrestrial route from the Levant to the Indian Ocean, but given the countries it would have to pass through (Lebanon and Iraq, to name two), it would have about as much chance of survival as a strand of gossamer stretched across a kick-boxing ring. And you can't lay a cable down the Suez Canal, partly because it would catch hell from anchors and dredgers, and partly because cable-laying ships move very slowly and would create an enormous traffic jam.

The only solution that is even remotely acceptable is to land the cable on Egypt's Mediterranean coast (which in practice means either Alexandria or Port Said) and then go overland to Suez, where the canal joins the Gulf of Suez, which in turn joins the Red Sea. The Red Sea is so shallow and so heavily trafficked, by the way, that all cables running through it must be plowed into the seafloor, which is a hassle, but obviously preferable to running a terrestrial route through the likes of Sudan and Somalia, which border it.

In keeping with its practice of running two parallel routes on terrestrial sections, FLAG is landing at both Alexandria and Port Said. From these cities the cables converge on Suez. Alexandria is far more important than Port Said as a cable nexus for the simple reason that it is at the westernmost extreme of the Nile Delta, so you can reach it from Europe without having to contend with the Nile. European cables running to Port Said, by contrast, must pass across the mouths of the Nile, where they are subjected to currents.

Engineer Mustafa Musalam, general manager of transmission for ARENTO's Alexandria office, is a stocky, affable, silver-haired gent. Egypt is one of those places where **Engineer** is used as a title, like **Doctor** or **Professor**, and Engineer Musalam bears the title well. In his personality and bearing he has at least as much in common with other highly competent engineers around the world as he does with other Egyptians. In defiance of ARENTO rules, he drives himself around in his own vehicle, a tiny, beat-up, but perfectly functional subcompact. An engineer of his stature is supposed to be chauffeured around in a company car. Most Egyptian service-industry professionals are masters at laying passive-aggressive head trips on their employers.

Half the time, when you compensate them, they make it clear that you have embarrassed them, and yourself, by grossly overdoing it—you have just gotten it totally wrong, really pissed down your leg, and placed them in a terribly awkward situation. The other half of the time, you have insulted them by being miserly. You never get it right. But Engineer Musalam, a logical and practical-minded sort, cannot abide the idea of a driver spending his entire day, every day, sitting in a car waiting for the boss to go somewhere. So he eventually threw up his hands and unleashed his driver on the job market.

Charitably, Engineer Musalam takes the view that the completion of the Asw�an High Dam tamed the Nile's current to the point where no one need worry about running cables to Port Said anymore. FLAG's surveyors obviously agree with him, because they chose Port Said as one of their landing points. On the other hand, FLAG's archenemy, SEA-ME-WE 3, will land only at Alexandria, because France Telecom's engineers refuse to lay cable across the Nile. SEA-ME-WE 3's redundant routes will run, instead, along the Desert Road and the Agricultural Road. Bandwidth buyers trying to choose between the two cables can presumably look forward to lurid sales presentations from FLAG marketers detailing the insane recklessness of SEA-ME-WE 3's approach, and vice versa.

At the dirt-and-duct level, the operation in Egypt is much like the one in Thailand. The work is being done by Consolidated Contractors, which is a fairly interesting multinational contracting firm that is based and funded in the Middle East but works all over the globe. Here it is laying six 100-mm ducts (10 inside Alexandria proper) as compared with only two in Thailand. These ducts are all PVC pipe, but FLAG's duct is made of a higher grade of PVC than the others—even than President Mubarak's duct.

That's right—in a nicely Pharaonic touch, one of the six ducts going into the ground here is the sole property of President Hosni Mubarak, or (presumably) whoever succeeds him as head of state. It is hard to envision why a head of state would want or need his own private tube full of air running underneath the Sahara. The obvious guess is that the duct might be used to create a secure communications system, independent of the civilian and military systems (the Egyptian military will own one of the six ducts, and ARENTO will own three). This, in and of itself, says something about the relationship between the military and the government in Egypt. It is hardly surprising when you consider that Mubarak's predecessor was murdered by the military during a parade.

Inside the city, where ten rather than six ducts are being prepared, they must occasionally sprout up out of the ground and run along the undersides of bridges and flyovers. In these sections it is easy to identify FLAG's duct because, unlike the others, it is galvanized steel instead of PVC. FLAG undoubtedly specified steel for its far greater protective value, but in so doing posed a challenge for Engineer Musalam, who knew that thieves would attack the system wherever they could reach it—not to take the cable but to get their hands on that tempting steel pipe. So, wherever the undersides of these bridges and flyovers are within 2 or 3 meters of ground level, Engineer Musalam has built in special measures to make it virtually impossible for thieves to get their hands on FLAG's pipe.

For the most part, the duct installation is a simple cut-and-cover operation, right down the median strip. But the median is crossed frequently by nicely paved, heavily trafficked U-turn routes. To cut or block one of these would be unthinkable, since no journey in Egypt is complete without numerous U-turns. It is therefore necessary to bore a horizontal tunnel under each one, run a 600-mm steel pipe down the tunnel, and finally thread the ducts through it. The tunnels are bored by laborers operating big manually powered augers. Under a sign reading Civil Works: Fiberoptic Link around the Globe, the men had left their street clothes carefully wrapped up in plastic bags, on the shoulder of the road. They had kicked off their shoes and changed into the traditional, loose, ankle-length garment. One by one, they disappeared into a tunnel barely big enough to lie down in, carrying empty baskets, then returned a few minutes later with baskets full of dirt, looking like extras in some new Hollywood costume drama: **The Ten Commandments Meets the Great Escape**.

We blundered across Engineer Musalam's path one afternoon. This was sheer luck, but also kind of inevitable: other than ditch diggers, the only people in the median strip of this highway are hacker tourists and ARENTO engineers. He was here because one of the crews working on FLAG had, while enlarging a manhole excavation, plunged the blade of their backhoe right through the main communications cable connecting Egypt to Libya—a 960-circuit coaxial line buried, sans conduit, in the same median. Libya had dropped off the net for a while until Mu'ammar Gadhafi's eastbound traffic could be shunted to a microwave relay chain and an ARENTO repair crew had been mobilized. The quality of such an operation is not measured by how frequently cables get broken (usually they are broken by other people) but by how quickly they get fixed afterward, and by this standard Engineer Musalam runs a tight ship. The mishap occurred on a Friday afternoon—the Muslim sabbath—the first day of a three-day weekend and a national holiday to boot—40 years to the day after the Suez Canal was handed over to Egypt. Nevertheless, the entire hierarchy was gathered around the manhole excavation, from ditch diggers hastily imported from another nearby site all the way up to Engineer Musalam.

The ditch diggers made the hole even larger, whittling out a place for one of the splicing technicians to sit. The technicians stood on the brink of the pit offering directions, and eventually they jumped into it and grabbed shovels; their toolboxes were lowered in after them on ropes, and their black dress trousers and crisp white shirts rapidly converged on the same color as the dust covered them. In the lee of an unburied concrete manhole nearby, a couple of men established a little refreshment center: one hubbly-bubbly and one portable stove, shooting flames like a miniature oil well fire, where they cranked out glass after glass of heavily sweetened tea. This struck me as more efficient than the American technique of sending a gofer down to the 7-Eleven for a brace of Super Big Gulps. Traffic swirled around the adjacent U-turn; motorists rolled their windows down and asked for directions, which were cheerfully given. Egyptian males are not afraid to hold hands with each other or to ask for directions, which does not mean that they should be confused with sensitive New Age males.

The mangled ends of the cable were cleanly hacksawed and stripped, and a 2-meter-long segment of the same type of cable was wrestled out of a car and brought into the pit. Two lengths of lead pipe were threaded onto it, later to serve as protective bandages for the splices, and then the splicing began, one conductor at a time. Engineer Musalam watched attentively while I badgered him with nerdy questions.He brought me up to speed on the latest submarine cable gossip. During the previous month, in mid-June, SEA-ME-WE 2 had been cut twice between Djibouti and India. Two cable ships, **Restorer** and **Enterprise**, had been sent to fix the breaks. But fire had broken out in the engine room of the **Enterprise** (maybe a problem with the dilithium crystals), putting it into repairs for four weeks. So **Restorer** had to fix both breaks. But because of bad weather, only one of the faults had been repaired as of July 26. In the meantime, all of SEA-ME-WE 2's traffic had been shunted to a satellite link reserved as a backup.

Satellite links have enough bandwidth to fill in for a second-generation optical cable like SEA-ME-WE 2 but not enough to replace a third-generation one like FLAG or SEA-ME-WE 3. The cable industry is therefore venturing into new and somewhat unexplored territory with the current generation of cables. It is out of the question to run such a system without having elaborate backup plans, and if satellites can't hack it anymore, the only possible backup is on another cable—almost by definition, a competing cable. So as intensely as rival companies may compete with each other for customers, they are probably cooperating at the same time by reserving capacity on each other's systems. This presumably accounts for the fact that they are eager to spread nasty information about each other but will never do so on the record.

I didn't know the exact route of SEA-ME-WE 3 and was intrigued to learn that it will be passing through the same building in Alexandria as SEA-ME-WE 1 and 2, which is also the same building that will be used by FLAG. In addition, there is a new submarine cable called Africa 1 that is going to completely encircle that continent, it being much easier to circumnavigate Africa with a cable-laying ship than to run ducts and cables across it (though I would like to see Alan Wall have a go at it). Africa 1 will also pass through Engineer

Musalam's building in Alexandria, which will therefore serve as the cross-connect among essentially all the traffic of Africa, Europe, and Asia.

Though Engineer Musalam is not the type who would come out and say it, the fact is that in a couple of years he's going to be running what is arguably the most important information nexus on the planet.

As the sun dropped behind the western Sahara (I imagined Mu'ammar Gadhafi out there somewhere, picking up his telephone to hear a fast busy signal), Engineer Musalam drove me into Alexandria in his humble subcompact to see this planetary nexus.

It is an immense neoclassical pile constructed in 1933 by the British to house their PTT operations. Since then, it has changed very little except for the addition of a window air conditioner in Engineer Musalam's office. The building faces Alexandria's railway station across an asphalt square crowded with cars, trucks, donkey carts, and pedestrians.

I do not think any other hacker tourist will ever make it inside this building. If you do so much as raise a camera to your face in its vicinity, an angry man in a uniform will charge up to you and let you get a very good look at the bayonet fixed to the end of his automatic weapon. So let me try to convey what it is like:

The adjective **Blade-Runneresque** means much to those who have seen the movie. (For those who haven't, just keep reading.) I will, however, never again be able to watch **Blade Runner**, because all of the buildings that looked so cool, so exquisitely art-directed in the movie, will now, to me, look like feeble efforts to capture a few traces of ARENTO's Alexandria station at night.

The building is a titanic structure that goes completely dark at night and becomes a maze of black corridors that appear to stretch on into infinity. Some illumination, and a great deal of generalized din, sifts in from the nearby square through broken windows. It has received very limited maintenance in the last half-century but will probably stand as long as the Pyramids. The urinals alone look like something out of Luxor. The building's cavernous stairwells consist of profoundly worn white marble steps winding around a central shaft that is occupied by an old-fashioned wrought-iron elevator with all of the guts exposed: rails, cables, counterweights, and so on. Litter and debris have accumulated at the bottom of these pits. At the top, nocturnal birds have found their way in through open or broken windows and now tear around in the blackness like Stealth fighters, hunting for insects and making eerie keening noises—not the twitter of songbirds but the alien screech of movie pterodactyls. Gaunt cats prowl soundlessly up and down the stairs. A big microwave relay tower has been planted on the roof, and the red aircraft warning lights hang in the sky like fat planets. They shed a vague illumination back into the building, casting faint cyan shadows. Looking into the building's courtyards you may see, for a moment, a human figure silhouetted in a doorway by blue fluorescent light. A chair sits next to a dust-fogged window that has been cracked open to let in cool night air. Down in the square, people are buying and selling, young men strolling hand in hand through a shambolic market scene. In the windows of apartment buildings across the street, women sit in their colorful but demure garments holding tumblers of sweet tea.

In the midst of all this, then, you walk through a door into a vast room, and there it is: the cable station, rack after rack after rack of gleaming Alcatel and Siemens equipment, black phone handsets for the order wires, labeled Palermo and Tripoli and Cairo. Taped to a pillar is an Arabic prayer and faded photograph of the faithful circling the Ka'aba. The equipment here is of a slightly older vintage than what we saw in Japan, but only because the cables are older; when FLAG and SEA-ME-WE 3 and Africa 1 come through, Engineer Musalam will have one of the building's numerous unused rooms scrubbed out and filled with state-of-the-art gear.

A few engineers pad through the place. The setup is instantly recognizable; you can see the same thing anywhere nerds are performing the kinds of technical hacks that keep modern governments alive. The Manhattan Project, Bletchley Park, the National Security Agency, and, I would guess, Saddam Hussein's weapons labs are all built on the same plan: a big space ringed by anxious, ignorant, heavily armed men, looking outward. Inside that perimeter, a surprisingly small number of hackers wander around through untidy offices making the world run.

If you turn your back on the equipment through which the world's bits are swirling, open one of the windows, wind up, and throw a stone pretty hard, you can just about bonk that used book peddler on the head. Because this place, soon to be the most important data nexus on the planet, happens to be constructed virtually on top of the ruins of the Great Library of Alexandria.

The Lalla Rookh

When William Thomson became Lord Kelvin and entered the second phase of his life—tooling around on his yacht, the **Lalla Rookh**—he appeared to lose interest in telegraphy and got sidetracked into topics that, on first reading, seem unrelated to his earlier interests—disappointingly mundane. One of these was depth sounding, and the other was the nautical compass.

At the time, depths were sounded by heaving a lead-weighted rope over the side of the ship and letting it pay out until it hit bottom. So far, so easy, but hauling thousands of meters of soggy rope, plus a lead weight, back onto the ship required the efforts of several sailors and took a long time. The US Navy ameliorated the problem by rigging it so that the weight could be detached and simply discarded on the bottom, but this only replaced one problem with another one in that a separate weight had to be carried for each sounding. Either way, the job was a mess and could be done only rarely. This probably explains why ships were constantly running aground in those days, leading to a relentless, ongoing massacre of crew and passengers compared to which today's problem of bombs and airliners is like a Sunday stroll through Disney World.

In keeping with his general practice of using subtlety where moronic brute force had failed, Kelvin replaced the soggy rope with a piano wire, which in turn enabled him to replace the heavy weight with a much smaller one. This idea might seem obvious to us now, but it was apparently quite the brainstorm. The tension in the wire was so light that a single sailor could reel it in by turning a spoked wooden wheel.

The first time Kelvin tried this, the wheel began to groan after a while and finally imploded. Dental hygienists, or people who floss the way they do (using extravagantly long pieces of floss and wrapping the used part around a fingertip) will already know why. The first turn of floss exerts only light pressure on the finger, but the second turn doubles it, and so on, until, as you are coming to the end of the process, your fingertip has turned a gangrenous purple. In the same way, the tension on Kelvin's piano wire, though small enough to be managed by one man, became enormous after a few hundred turns. No reasonable wheel could endure such stress.

Chagrined and embarrassed, Kelvin invented a stress-relief mechanism. On one side of it the wire was tight, on the other side it was slack and could be taken up by the wheel without compressing the hub. Once this was out of the way, the challenge became how to translate the length of piano wire that had been paid out into an accurate depth reading. One could never assume that the wire ran straight down to the bottom. Usually the vessel was moving, so the lead weight would trail behind it. Furthermore, a line stretched between two points in this way forms a curve known to mathematicians as a catenary, and of course the curve is longer than a straight line between the same two points. Kelvin had to figure out what sorts of catenary curves his piano wire would assume under various conditions of vessel speed and ocean depth—an essentially tedious problem that seems well beneath the abilities of the father of thermodynamics.

In any case, he figured it out and patented everything. Once again he made a ton of money. At the same time, he revolutionized the field of bathymetry and probably saved a large number of lives by making it easier for mariners to take frequent depth soundings. At the same time, he invented a vastly improved form of ship's compass which was as big an improvement over the older models as his depth-sounding equipment was over the soggy rope. Attentive readers will not be surprised to learn that he patented this device and made a ton of money from it.

Kelvin had revolutionized the art of finding one's way on the ocean, both in the vertical (depth) dimension and in the horizontal (compass) dimensions. He had made several fortunes in the process and spent a great deal of his intellectual gifts on pursuits that, I thought at first, could hardly have been less relevant to his earlier work on undersea cables. But that was my problem, not his. I didn't figure out what he was up to until very close to the ragged end of my hacker tourism binge

Slack

The first time a cable-savvy person uses the word **slack** in your presence, you'll be tempted to assume he is using it in the loose, figurative way—as a layperson uses it. After the eightieth or ninetieth time, and after the cable guy has spent a while talking about the seemingly paradoxical notion of slack control and extolling the sophistication of his ship's slack control systems and his computer's slack numerical-simulation software, you begin to understand that slack plays as pivotal a role in a cable lay as, say, thrust does in a moon mission.

He who masters slack in all of its fiendish complexity stands astride the cable world like a colossus; he who is clueless about slack either snaps his cable in the middle of the ocean or piles it in a snarl on the ocean floor—which is precisely what early 19th-century cable layers spent most of their time doing.

The basic problem of slack is akin to a famous question underlying the mathematical field of fractals: How long is the coastline of Great Britain? If I take a wall map of the isle and measure it with a ruler and multiply by the map's scale, I'll get one figure. If I do the same thing using a set of large-scale ordnance survey maps, I'll get a much higher figure because those maps will show zigs and zags in the coastline that are polished to straight lines on the wall map. But if I went all the way around the coast with a tape measure, I'd pick up even smaller variations and get an even larger number. If I did it with calipers, the number would be larger still. This process can be repeated more or less indefinitely, and so it is impossible to answer the original question straightforwardly. The length of the coastline of Great Britain must be defined in terms of fractal geometry.

A cross-section of the seafloor has the same property. The route between the landing station at Songkhla, Thailand, and the one at Lan Tao Island, Hong Kong, might have a certain length when measured on a map, say 2,500 kilometers. But if you attach a 2,500-kilometer cable to Songkhla and, wearing a diving suit, begin manually unrolling it across the seafloor, you will run out of cable before you reach the public beach at Tong Fuk. The reason is that the cable follows the bumpy topography of the seafloor, which ends up being a longer distance than it would be if the seafloor were mirror-flat.

Over long (intercontinental) distances, the difference averages out to about 1 percent, so you might need a 2,525-kilometer cable to go from Songkhla to Lan Tao. The extra 1 percent is slack, in the sense that if you grabbed the ends and pulled the cable infinitely tight (bar tight, as they say in the business), it would theoretically straighten out and you would have an extra 25 kilometers. This slack is ideally molded into the contour of the seafloor as tightly as a shadow, running straight and true along the surveyed course. As little slack as possible is employed, partly because cable costs a lot of money (for the FLAG cable, $16,000 to $28,000 per kilometer, depending on the amount of armoring) and partly because loose coils are just asking for trouble from trawlers and other hazards. In fact, there is so little slack (in the layperson's sense of the word) in a well-laid cable that it cannot be grappled and hauled to the surface without snapping it.

This raises two questions, one simple and one nauseatingly difficult and complex. First, how does one repair a cable if it's too tight to haul up?

The answer is that it must first be pulled slightly off the seafloor by a detrenching grapnel, which is a device, meant to be towed behind a ship, that rolls across the bottom of the ocean on two fat tractor tires. Centered between those tires is a stout, wicked-looking, C-shaped hook, curving forward at the bottom like a stinger. It carves its way through the muck and eventually gets under the cable and lifts it up and holds it steady just above the seafloor. At this point its tow rope is released and buoyed off.

The ship now deploys another towed device called a cutter, which, seen from above, is shaped like a manta ray. On the top and bottom surfaces it carries V-shaped blades. As the ship makes another pass over the detrenching grapnel, one of these blades catches the cable and severs it.

It is now possible to get hold of the cut ends, using other grapnels. A cable repair ship carries many different kinds of grapnels and other hardware, and keeping track of them and their names (like "long prong Sam") is sort of like taking a course in exotic marine zoology. One of the ends is hauled up on board ship, and a new length of cable is spliced onto it solely to provide excess slack. Only now can both ends of the cable be brought aboard the ship at the same time and the final splice made.

But now the cable has way too much slack. It can't just be dumped overboard, because it would form an untidy heap on the bottom, easily snagged. Worse, its precise location would not be known, which is suicide from a legal point of view. As long as a cable's position is precisely known and marked on charts, avoiding it is the responsibility of every mariner who comes that way. If it's out of place, any snags are the responsibility of the cable's owners.

So the loose loop of cable must be carefully lowered to the bottom on the end of a rope and arranged into a sideways bight that lies alongside the original route of the cable something like an oxbow lake beside a river channel. The geometry of this bight is carefully recorded with sidescan sonar so that the information can be forwarded to the people who update the world's nautical charts.

One problem: now you have a rope between your ship's winch and the recently laid cable. It looks like an old-fashioned, hairy, organic jute rope, but it has a core of steel. It is a badass rope, extremely strong and heavy and expensive. You could cut it off and drop it, but this would waste money and leave a wild rope trailing across the seafloor, inviting more snags.

So at this point you deploy your submersible remotely operated vehicle (ROV) on the end of an umbilical. It rolls across the seabed on its tank tracks, finds the rope, and cuts it with its terrifying hydraulic guillotine.

Sad to say, that was the answer to the easy question. The hard one goes like this: You are the master of a cable ship just off Songkhla, and you have taken on 2,525 kilometers of cable which you are about to lay along the 2500-kilometer route between there and Tong Fuk Beach on Lan Tao Island. You have the 1 percent of slack required. But 1 percent is just an average figure for the whole route. In some places the seafloor is rugged and may need 5 percent slack; in others it is perfectly flat and the cable may be laid straight as a rod. Here's the question: How do you ensure that the extra 25 kilometers ends up where it's supposed to?

Remember that you are on a ship moving up and down on the waves and that you will be stretching the cable out across a distance of several kilometers between the ship and the contact point on the ocean floor, sometimes through undersea currents. If you get it wrong, you'll get suspensions in the cable, which will eventually develop into faults, or you'll get loops, which will be snagged by trawlers. Worse yet, you might actually snap the cable. All of these, and many more entertaining things, happened during the colorful early years of the cable business.

The answer has to do with slack control. And most of what is known about slack control is known by Cable & Wireless Marine. AT&T presumably knows about slack control too, but Cable & Wireless Marine has twice as many ships and dominates the deep-sea cable-laying industry. The Japanese can lay cable in shallow water and can repair it anywhere. But the reality is that when you want to slam a few thousand kilometers of state-of-the-art optical fiber across a major ocean, you call Cable & Wireless Marine, based in England. That is pretty much what FLAG did several years ago.

In which the Hacker Tourist treks to Land's end, the

haunt of Druids, Pirates, and Telegraphers.

An idyllic hike to the tiny Cornish town of Porthcurno. More flagon hoisting at the Cable Station. Lord Kelvin's handiwork examined and explained. Early bits. The surveyors of the oceans in Chelmsford, and how computers play an essential part in their work. Alexander Graham Bell, the second Supreme Ninja Hacker Mage Lord, and his misguided analog detour. Legacy of Kelvin, Bell, and FLAG to the wired world.

50° 3.965' N, 5° 42.745 WLand's End, Cornwall, England

As anyone can see from a map of England, Cornwall is a good jumping-off place for cables across the Atlantic, whether they are laid westward to the Americas or southward to Spain or the Azores. A cable from this corner of the island needs to traverse neither the English Channel nor the Irish Sea, both of which are shallow and fraught with shipping. Cornwall also possesses the other necessary prerequisite of a cable landing site in that it is an ancient haunt of pirates and smugglers and is littered with ceremonial ruins left behind by shadowy occult figures. The cable station here is called Porthcurno.

Not knowing exactly where Porthcurno is (it is variously marked on maps, if marked at all), the hacker tourist can find it by starting at Land's End, which is unambiguously located (go to England; walk west until the land ends). He can then walk counterclockwise around the coastline. The old fractal question of "How long is the coastline of Great Britain" thus becomes more than a purely abstract exercise. The answer is that in Cornwall it is much longer than it looks, because the fractal dimension of the place is high—Cornwall is bumpy. All of the English people I talked to before getting here told me that the place was rugged and wild and beautiful, but I snidely assumed that they meant "by the standards of England." As it turns out, Cornwall is rugged and wild and beautiful even by the standards of, say, Northern California. In America we assume that any place where humans have lived for more than a generation has been pretty thoroughly screwed up, so it is startling to come to a place where 2,000-year-old ruins are all over the place and find that it is still virtually a wilderness.

From Land's End you can reach Porthcurno in two or three hours, depending on how much time you spend gawking at views, clambering up and down cliffs, exploring caves, and taking dips at small perfect beaches that can be found wedged into clefts in the rock.

Cables almost never land in industrial zones, first because such areas are heavily traveled and frequently dredged, second because of pure geography. Industry likes rivers, which bring currents, which are bad for cables. Cities like flat land. But flat land above the tide line implies a correspondingly gentle slope below the water, meaning that the cable will pass for a greater distance through the treacherous shallows. Three to thirty meters is the range of depth where most of the ocean dynamics are and where cable must be armored. But in wild places like Porthcurno or Lan Tao Island, rivers are few and small, and the land bursts almost vertically from the sea. The same geography, of course, favors pirates and smugglers.

The company that laid the first part of it was called the Falmouth, Gibraltar and Malta Telegraph Company, which is odd because the cable never went to Falmouth—a major port some 50 kilometers from Porthcurno. Enough anchors had hooked cables, even by that point, that "major port" and "submarine cable station" were seen to be incompatible, so the landing site was moved to Porthcurno.That was just the beginning: the company (later called the Eastern Cable Company, after all the segments between Porthcurno and Darwin merged) was every bit as conscious of the importance of redundancy as today's Internet architects—probably more so, given the unreliability of early cables. They ran another cable from Porthcurno to the Azores and then to Ascension Island, where it forked: one side headed to South America while the other went to Cape Town and then across the Indian Ocean. Subsequent transatlantic cables terminated at Porthcurno as well.

Many of the features that made Cornwall attractive to cable operators also made it a suitable place to conduct transatlantic radio experiments, and so in 1900 Guglielmo Marconi himself established a laboratory on Lizard Point, which is directly across the bay from Porthcurno, some 30 kilometers distant. Marconi had another station on the Isle of Wight, a few hundred kilometers to the east, and when he succeeded in sending messages between the two, he constructed a more powerful transmitter at the Lizard station and began trying to send messages to a receiver in Newfoundland. The competitive threat to the cable industry could hardly have been more obvious, and so the Eastern Telegraph Company raised a 60-meter mast above its Porthcurno site, hoisted an antenna, and began eavesdropping on Marconi's transmissions. A couple of decades later, after the Italian had worked the bugs out of the system, the government stepped in and arranged a merger between his company and the submarine cable companies to create a new, fully integrated communications monopoly called Cable & Wireless.

50° 2.602′ N5° 39.054′ WMuseum of Submarine Telegraphy, Porthcurno, Cornwall

On a sunny summer day, Porthcurno Beach was crowded with holiday makers. The vast majority of these were scantily clad and tended to face toward the sun and the sea. The fully clothed and heavily shod tourists with their backs to the water were the hacker tourists; they were headed for a tiny, windowless cement blockhouse, scarcely big enough to serve as a one-car garage, planted at the apex of the beach. There was a sign on the wall identifying it as the Museum of Submarine Telegraphy and stating that it is open only on Wednesday and Friday.

This was appalling news. We arrived on a Monday morning, and our maniacal schedule would not brook a two-day wait. Stunned, heartbroken, we walked around the thing a couple of times, which occupied about 30 seconds. The lifeguard watched us uneasily. We admired the brand-new manhole cover set into the ground in front of the hut, stamped with the year '96, which strongly suggested a connection with FLAG. We wandered up the valley for a couple of hundred meters until it opened up into a parking lot for beach-goers, surrounded by older white masonry buildings. These were well-maintained but did not seem to be used for much. We peered at a couple of these and speculated (wrongly, as it turned out) that they were the landing station for FLAG.

Tantalizing hints were everywhere: the inevitable plethora of manholes, networked to one another by long straight strips of new pavement set into the parking lot and the road. Nearby, a small junkheap containing several lengths of what to the casual visitor might look like old, dirty pipe but which on closer examination proved to be hunks of discarded coaxial cable. But all the buildings were locked and empty, and no one was around.

Our journey seemed to have culminated in failure. We then noticed that one of the white buildings had a sign on the door identifying it as The Cable Station—Free House. The sign was adorned with a painting of a Victorian shore landing in progress—a line of small boats supporting a heavy cable being payed out from a sailing ship anchored in Porthcurno Bay.

After coming all this way, it seemed criminal not to have a drink in this pub. By hacker tourist standards, a manhole cover counts as a major attraction, and so it was almost surreal to have stumbled across a place that had seemingly been conceived and built specifically for us. Indeed, we were the only customers in the place. We admired the photographs and paintings on the walls, which all had something or other to do with cables. We made friends with Sally the Dog, chatted with the proprietress, grabbed a pint, and went out into the beer garden to drown our sorrows.

Somewhat later, we unburdened ourselves to the proprietress, who looked a bit startled to learn of our strange mission, and said, "Oh, the fellows who run the museum are inside just now."

Faster than a bit speeding down an optical fiber we were back inside the pub where we discovered half a dozen distinguished gentlemen sitting around a table, finishing up their lunches. One of them, a tall, handsome, craggy sort, apologized for having ink on his fingers. We made some feeble effort to explain the concept of **Wired** magazine (never easy), and they jumped up from their seats, pulled key chains out of their pockets, and took us across the parking lot, through the gate, and into the museum proper. We made friends with Minnie the Cable Dog and got the tour. Our primary guides were Ron Werngren (the gent with ink on his fingers, which I will explain in a minute) and John Worrall, who is the cheerful, energetic, talkative sort who seems to be an obligatory feature of any cable-related site.

All of these men are retired Cable & Wireless employees. They sketched in for us the history of this strange compound of white buildings. Like any old-time cable station, it housed the equipment for receiving and transmitting messages as well as lodgings and support services for the telegraphers who manned it. But in addition it served as the campus of a school where Cable & Wireless foreign service staff were trained, complete with dormitories, faculty housing, gymnasium, and dining hall.

The whole campus has been shut down since 1970. In recent years, though, the gentlemen we met in the pub, with the assistance of a local historical trust, have been building and operating the Museum of Submarine Telegraphy here. These men are of a generation that trained on the campus shortly after World War II, and between them they have lived and worked in just as many exotic places as the latter-day cable guys we met on Lan Tao Island: Buenos Aires, Ascension Island, Cyprus, Jordan, the West Indies, Saudi Arabia, Bahrain, Trinidad, Dubai.

Fortunately, the tiny hut above the beach is not the museum. It's just the place where the cables are terminated. FLAG and other modern cables bypass it and terminate in a modern station up at the head of the valley, so
all of the cables in this hut are old and out of service. They are labeled with the names of the cities where they terminate: Faial in the Azores, Brest in France, Bilbao in Spain, Gibraltar 1, Saint John's in Newfoundland, the Isles of Scilly, two cables to Carcavelos in Portugal, Vigo in Spain, Gibraltar 2 and 3. From this hut, the wires proceed up the valley a couple hundred meters to the cable station proper, which is encased in solid rock.

During World War II, the Porthcurno cable nexus was such a painfully obvious target for a Nazi attack that a detachment of Cornish miners were brought in to carve a big tunnel out of a rock hill that rises above the campus. This turned out to be so wet that it was necessary to then construct a house inside the tunnel, complete with pitched roof, gutters, and downspouts to carry away the eternal drizzle of groundwater. The strategically important parts of the cable station were moved inside. Porthcurno Bay and the Cable & Wireless campus were laced with additional defensive measures, like a fuel-filled pipe underneath the water to cremate incoming Huns.

Now the house in the tunnel is the home of the museum. It is sealed from the outside world by two blast doors, each of which consists of a foot-thick box welded together from inch-thick steel plate. The inner door has a gasket to keep out poison gas. Inside, the building is clean and almost cozy, and except for the lack of windows, one is not conscious of being underground.

Practically the first thing we saw upon entering was a fully functional Kelvin mirror galvanometer—the exquisitely sensitive detector that sent Wildman Whitehouse into ignominy, made the first transatlantic cable useful, and earned William Thomson his first major fortune. Most of its delicate innards are concealed within a metal case. The beam of light that reflects off its tiny twisting mirror shines against a long horizontal screen of paper, marked and numbered like a yardstick, extending about 10 inches on either side of a central zero point. The light forms a spot on this screen about the size and shape of a dime cut in half. It is so sensitive that merely touching the machine's case—grounding it—causes the spot of light to swing wildly to one end of the scale.

At Porthcurno this device was used for more than one purpose. One of the most important activities at a cable station is pinpointing the locations of faults, which is done by measuring the resistance in the cable. Since the resistance per unit of length is a known quantity, a precise measurement of resistance gives the distance to the fault. Measuring resistance was done by use of a device called a Wheatstone bridge. The museum has a beautiful one, built in a walnut box with big brass knobs for dialing in resistances. Use of the Wheatstone bridge relies on achieving a null current with the highest attainable level of precision, and for this purpose, no instrument on earth was better suited than the Kelvin mirror galvanometer. Locating a mid-ocean fault in a cable therefore was reduced to a problem of twiddling the dials on the Wheatstone bridge until the galvanometer's spot of light was centered on the zero mark.

The reason for the ink on Ron Werngren's fingers became evident when we moved to another room and beheld a genuine Kelvin siphon recorder, which he was in the process of debugging. This machine represented the first step in the removal of humans from the global communications loop that has culminated in the machine room at cable landing stations like Ninomiya.

After Kelvin's mirror galvanometer became standard equipment throughout the wired world, every message coming down the cables had to pass, briefly, through the minds of human operators such as the ones who were schooled at the Porthcurno campus. These were highly trained young men in slicked hair and starched collars, working in teams of two or three: one to watch the moving spot of light and divine the letters, a second to write them down, and, if the message were being relayed down another cable, a third to key it in again.

It was clear from the very beginning that this was an error-prone process, and when the young men in the starched collars began getting into fistfights, it also became clear that it was a job full of stress. The stress derived from the fact that if the man watching the spot of light let his attention wander for one moment, information would be forever lost. What was needed was some mechanical way to make a record of the signals coming down the cable. But because of the weakness of these signals, this was no easy job.

Lord Kelvin, never one to rest on his laurels, solved the problem with the siphon recorder. For all its historical importance, and for all the money it made Kelvin, it is a flaky-looking piece of business. There is a reel of paper tape which is drawn steadily through the machine by a motor. Mounted above it is a small reservoir containing perhaps a tablespoon of ink. What looks like a gossamer strand emerges from the ink and bends around through some delicate metal fittings so that its other end caresses the surface of the moving tape. This strand is actually an extremely thin glass tube that siphons the ink from the reservoir onto the paper. The idea is that the current in the cable, by passing through an electromechanical device, will cause this tube to move slightly to one side or the other, just like the spot of light in the mirror galvanometer. But the current in the old cables was so feeble that even the infinitesimal contact point between the glass tube and the tape still induced too much friction, so Kelvin invented a remarkable kludge: he built a vibrator into the system that causes the glass tube to thrum like a guitar string so that its point of contact on the paper is always in slight motion.

Dynamic friction (between moving objects) is always less than static friction (between objects that are at rest with respect to each other). The vibration in the glass siphon tube reduced the friction against the paper tape to the point where even the weak currents in a submarine cable could move it back and forth. Movement to one side of the tape represented a dot, to the other side a dash. We prevailed upon Werngren to tap out the message Get Wired.The result is on the cover of this magazine, and if you know Morse code you can pick the letters out easily.

The question naturally arises: How does one go about manufacturing a hollow glass tube thinner than a hair? More to the point, how did they do it 100 years ago? After all, as Worrall pointed out, they needed to be able to repair these machines when they were posted out on Ascension Island. The answer is straightforward and technically sweet: you take a much thicker glass tube, heat it over a Bunsen burner until it glows and softens, and then pull sharply on both ends. It forms a long, thin tendril, like a string of melted cheese stretching away from a piece of pizza. Amazingly, it does not close up into a solid glass fiber, but remains a tube no matter how thin it gets.

Exactly the same trick is used to create the glass fibers that run down the center of FLAG and other modern submarine cables: an ingot of very pure glass is heated until it glows, and then it is stretched. The only difference is that these are solid fibers rather than tubes, and, of course, it's all done using machines that assure a consistent result.

Moving down the room, we saw a couple of large tabletops devoted to a complete, functioning reproduction of a submarine cable system as it might have looked in the 1930s. The only difference is that the thousands of miles of intervening cable are replaced with short jumper wires so that transmitter, repeaters, and receiver are contained within a single room.

All the equipment is built the way they don't build things anymore: polished wooden cabinets with glass tops protecting gleaming brass machinery that whirrs and rattles and spins. Relays clack and things jiggle up and down. At one end of the table is an autotransmitter that reads characters off a paper tape, translates them into Morse code or cable code, and sends its output, in the form of a stream of electrical pulses, to a regenerator/retransmitter unit. In this case the unit is only a few feet away, but in practice it would have been on the other end of a long submarine cable, say in the Azores. This regenerator/retransmitter unit sends its output to a twin siphon-tube recorder which draws both the incoming signal (say, from London) and the outgoing signal as regenerated by this machine on the same paper tape at the same time. The two lines should be identical. If the machine is not functioning correctly, it will be obvious from a glance at the tape.

The regenerated signal goes down the table (or down another submarine cable) to a machine that records the message as a pattern of holes punched in tape. It also goes to a direct printer that hammers out the words of the message in capital letters on another moving strip of paper. The final step is a gummer that spreads stickum on the back of the tape so that it may be stuck onto a telegraph form. (They tried to use pregummed tape, but in the tropics it only coated the machinery with glue.)

Each piece of equipment on this tabletop is built around a motor that turns over at the same precise frequency. None of it would work—no device could communicate with any other device—unless all of those motors were spinning in lockstep with one another. The transmitter, regenerator/retransmitter, and printer all had to be in sync even though they were thousands of miles apart.

This feat is achieved by means of a collection of extremely precise analog machinery. The heart of the system is another polished box that contains a vibrating reed, electromagnetically driven, thrumming along at 30 cycles per second, generating the clock pulses that keep all the other machines turning over at the right pace. The reed is as precise as such a thing can be, but over time it is bound to drift and get out of sync with the other vibrating reeds in the other stations.

In order to control this tendency, a pair of identical pendulum clocks hang next to each other on the wall above. These clocks feed steady, one-second timing pulses into the box housing the reed. The reed, in turn, is driving a motor that is geared so that it should turn over at one revolution per second, generating a pulse with each revolution. If the frequency of the reed's vibration begins to drift, the motor's speed will drift along with it, and the pulse will come a bit too early or a bit too late. But these pulses are being compared with the steady one-second pulses generated by the double pendulum clock, and any difference between them is detected by a feedback system that can slightly speed up or slow down the vibration of the reed in order to correct the error. The result is a clock so steady that once one of them is set up in, say, London, and another is set up in, say, Cape Town, the machinery in those two cities will remain synched with each other indefinitely.

This is precisely the same function that is performed by the quartz clock chip at the heart of any modern computing device. The job performed by the regenerator/retransmitter is also perfectly recognizable to any modern digitally minded hacker tourist: it is an analog-to-digital converter. The analog voltages come down the cable into the device, the circuitry in the box decides whether the signal is a dot or a dash (or if you prefer, a 1 or a 0), and then an electromagnet physically moves one way or the other, depending on whether it's a dot or a dash. At that moment, the device is strictly digital. The electromagnet, by moving, then closes a switch that generates a new pulse of analog voltage that moves on down the cable. The hacker tourist, who has spent much of his life messing around with invisible, ineffable bits, can hardly fail to be fascinated when staring into the guts of a machine built in 1927, steadily hammering out bits through an electromechanical process that can be seen and even touched.

As I started to realize, and as John Worrall and many other cable-industry professionals subsequently told me, there have been new technologies but no new ideas since the turn of the century. Alas for Internet chauvinists who sneer at older, "analog" technology, this rule applies to the transmission of digital bits down wires, across long distances. We've been doing it ever since Morse sent "What hath God wrought!" from Washington to Baltimore.

(Latitude & longitude unknown)Cable & Wireless MarineChelmsford, England

[Note: I left my GPS receiver on a train in Bristol and had to do without it for a couple of weeks until Mr. Gallagher, station supervisor at Preston, Lancashire, miraculously found it and sent it back to me. Chelmsford is a half-hour train ride northeast of London.]

When last we saw our hypothetical cable-ship captain, sitting off of Songkhla with 2,525 kilometers of very expensive cable, we had put him in a difficult spot by asking the question of how he could ensure that his 25 kilometers of slack ended up in exactly the right place. Essentially the same question was raised a few years ago when FLAG approached Cable & Wireless Marine and said, in effect: "We are going to buy 28,000 kilometers of fancy cable from AT&T and KDD, and we would like to have it go from England to Spain to Italy to Egypt to Dubai to India to Thailand to Hong Kong to China to Korea to Japan. We would like to pay for as little slack as possible, because the cable is expensive. What little slack we do buy needs to go in exactly the right place, please. What should we do next?"

So it was that Captain Stuart Evans's telephone rang. At the time (September 1992), he was working for a company called Worldwide Ocean Surveying, but by the time we met him, that company had been bought out by Cable & Wireless Marine, of which he is now general manager—survey. Evans is a thoroughly pleasant middle-aged fellow, a former merchant marine captain, who seemed just a bit taken aback that anyone would care about the minute details of what he and his staff do for a living. A large part of being a hacker tourist is convincing people that you are really interested in the nitty-gritty and not just looking for a quick, painless sound bite or two; once this is accomplished, they always warm to the task, and Captain Evans was no exception.Evans's mission was to help FLAG select the most economical and secure route. The initial stages of the process are straightforward: choose the landing sites and then search existing data concerning the routes joining those sites. This is referred to as a desk search, with mild but unmistakable condescension. Evans and his staff came up with a proposed route, did the desk search, and sent it to FLAG for approval. When FLAG signed off on this, it was time to go out and perform the real survey. This process ran from January to September 1994.

Each country uses the same landing sites over and over again for each new cable, so you might think that the routes from, say, Porthcurno to Spain would be well known by now. In fact, every new cable passes over some virgin territory, so a survey is always necessary. Furthermore, the territory does not remain static. There are always new wrecks, mobile sand waves, changes in anchorage patterns, and other late-breaking news.

To lay a cable competently you must have a detailed survey of a corridor surrounding the intended route. In shallow water, you have relatively precise control over where the cable ends up, but the bottom can be very irregular, and the cable is likely to be buried into the seabed. So you want a narrow (1 kilometer wide) corridor with high resolution. In deeper water, you have less lateral control over the descending cable, but at the same time the phenomena you're looking at are bigger, so you want a survey corridor whose width is 2 to 3 times the ocean depth but with a coarser resolution. A resolution of 0.5 percent of the depth might be considered a minimum standard, though the FLAG survey has it down to 0.25 percent in most places. So, for example, in water 5,000 meters deep, which would be a somewhat typical value away from the continental shelf, the survey corridor would be 10 to 15 kilometers in width, and a good vertical resolution would be 12 meters.

The survey process is almost entirely digital. The data is collected by a survey ship carrying a sonar rig that fires 81 beams spreading down and out from the hull in a fan pattern. At a depth of 5,000 meters, the result, approximately speaking, is to divide the 10-kilometer-wide corridor into grid squares 120 meters wide and 175 meters long and get the depth of each one to a precision of some 12 meters.

The raw data goes to an onboard SPARCstation that performs data assessment in real time as a sort of quality assurance check, then streams the numbers onto DAT cassettes. The survey team is keeping an eye on the results, watching for any formations through which cable cannot be run. These are found more frequently in the Indian than in the Atlantic Ocean, mostly because the Atlantic has been charted more thoroughly.

Steep slopes are out. A cable that traverses a steep slope will always want to slide down it sideways, secretly rendering every nautical chart in the world obsolete while imposing unknown stresses on the cable. This and other constraints may throw an impassable barrier across the proposed route of the cable. When this happens, the survey ship has to backtrack, move sideways, and survey other corridors parallel and adjacent to the first one, gradually building a map of a broader area, until a way around the obstruction is found. The proposed route is redrafted, and the survey ship proceeds.

The result is a shitload of DAT tapes and a good deal of other data as well. For example, in water less than 1,200 meters deep, they also use sidescan sonar to generate analog pictures of the bottom—these look something like black-and-white photographs taken with a point light source, with the exception that shadows are white instead of black. It is possible to scan the same area from several different directions and then digitally combine the images to make something that looks just like a photo. This may provide crucial information that would never show up on the survey —for example, a dense pattern of anchor scars indicates that this is not a good place to lay a cable. The survey ship can also drop a flowmeter that will provide information about currents in the ocean.

The result of all this, in the case of the FLAG survey, was about a billion data points for the bathymetric survey alone, plus a mass of sidescan sonar plots and other documentation. The tapes and the plots filled a room about 5 meters square all the way to the ceiling. The quantity of data involved was so vast that to manage it on paper, while it might have been theoretically possible given unlimited resources, was practically impossible given that FLAG is run by mortals and actually has to make money. FLAG is truly an undertaking of the digital age in that it simply couldn't have been accomplished without the use of computers to manage the data.Evans's mission was to present FLAG with a final survey report. If he had done it the old-fashioned way, the report would have occupied some 52 linear feet of shelf space, plus several hefty cabinets full of charts, and the inefficiency of dealing with so much paper would have made it nearly impossible for FLAG's decision makers }to grasp everything.

Instead, Evans bought FLAG a PC and a plotter. During the summer of 1994, while the survey data was still being gathered, he had some developers write browsing software. Keeping in mind that FLAG's investors were mostly high-finance types with little technical or nautical background, they gave the browser a familiar, easy-to-use graphical user interface. The billion data points and the sidescan sonar imagery were boiled down into a form that would fit onto 5 CD-ROMs, and in that form the final report was presented to FLAG at the end of 1994. When FLAG's decision makers wanted to check out a particular part of the route, they could zoom in on it by clicking on a map, picking a small square of ocean, and blowing it up to reveal sev-eral different kinds of plots: a topographic map of the seafloor, information abstracted from the sidescan sonar images, a depth profile along the route, and another profile showing the consistency of the bot-tom—whether muck, gravel, sand, or hard rock. All of these could be plotted out on meterwide sheets of paper that provided a much higher-resolution view than is afforded by the computer screen.

This represents a noteworthy virtuous circle—a self-amplifying trend. The development of graphical user interfaces has led to rapid growth in personal computer use over the last decade, and the coupling of that technology with the Internet has caused explosive growth in the use of the World Wide Web, generating enormous demand for bandwidth. That (in combination, of course, with other demands) creates a demand for submarine cables much longer and more ambitious than ever before, which gets investors excited—but the resulting project is so complex that the only way they can wrap their minds around it and make intelligent decisions is by using a computer with a graphical user interface.

Hacking wires

As you may have figured out by this point, submarine cables are an incredible pain in the ass to build, install, and operate. Hooking stuff up to the ends of them is easy by comparison. So it has always been the case that cables get laid first and then people begin trying to think of new ways to use them. Once a cable is in place, it tends to be treated not as a technological artifact but almost as if it were some naturally occurring mineral formation that might be exploited in any number of different ways.

This was true from the beginning. The telegraphy equipment of 1857 didn't work when it was hooked up to the first transatlantic cable. Kelvin had to invent the mirror galvanometer, and later the siphon recorder, to make use of it. Needless to say, there were many other Victorian hackers trying to patent inventions that would enable more money to be extracted from cables. One of these was a Scottish-Canadian-American elocutionist named Alexander Graham Bell, who worked out of a laboratory in Boston.

Bell was one of a few researchers pursuing a hack based on the phenomenon of resonance. If you open the lid of a grand piano, step on the sustain pedal, and sing a note into it, such as a middle C, the strings for the piano's C keys will vibrate sympathetically, while the D strings will remain still. If you sing a D, the D strings vibrate and the C strings don't. Each string resonates only at the frequency to which it has been tuned and is deaf to other frequencies.

If you were to hum out a Morse code pattern of dots and dashes, all at middle C, a deaf observer watching the strings would notice a corresponding pattern of vibrations. If, at the same time, a second person was standing next to you humming an entirely different sequence of dots and dashes, but all on the musical tone of D, then a second deaf observer, watching the D strings, would be able to read that message, and so on for all the other tones on the scale. There would be no interference between the messages; each would come through as clearly as if it were the only message being sent. But anyone who wasn't deaf would hear a cacophony of noise as all the message senders sang in different rhythms, on different notes. If you took this to an extreme, built a special piano with strings tuned as close to each other as possible, and trained the message senders to hum Morse code as fast as possible, the sound would merge into an insane roar of white noise.

Electrical oscillations in a wire follow the same rules as acoustical ones in the air, so a wire can carry exactly the same kind of cacophony, with the same results. Instead of using piano strings, Bell and others were using a set of metal reeds like the ones in a harmonica, each tuned to vibrate at a different frequency. They electrified the reeds in such a way that they generated not only acoustical vibrations but corresponding electrical ones. They sought to combine the electrical vibrations of all these reeds into one complicated waveform and feed it into one end of a cable. At the far end of the cable, they would feed the signal into an identical set of reeds. Each reed would vibrate in sympathy only with its counterpart on the other end of the wire, and by recording the pattern of vibrations exhibited by that reed, one could extract a Morse code message independent of the other messages being transmitted on the other reeds. For the price of one wire, you could send many simultaneous coded messages and have them all sort themselves out on the other end.

To make a long story short, it didn't work. But it did raise an interesting question. If you could take vibrations at one frequency and combine them with vibrations at another frequency, and another, and another, to make a complicated waveform, and if that waveform could be transmitted to the other end of a submarine cable intact, then there was no reason in principle why the complex waveform known as the human voice couldn't be transmitted in the same way. The only difference would be that the waves in this case were merely literal representations of sound waves, rather than Morse code sequences transmitted at different frequencies. It was, in other words, an analog hack on a digital technology.

We have all been raised to think of the telephone as a vast improvement on the telegraph, as the steamship was to the sailing ship or the electric lightbulb to the candle, but from a hacker tourist's point of view, it begins to seem like a lamentable wrong turn. Until Bell, all telegraphy was digital. The multiplexing system he worked on was purely digital in concept even if it did make use of some analog properties of matter (as indeed all digital equipment does). But when his multiplexing scheme went sour, he suddenly went analog on us.

Fortunately, the story has a happy ending, though it took a century to come about. Because analog telephony did not require expertise in Morse code, anyone could take advantage of it. It became enormously popular and generated staggering quantities of revenue that underwrote the creation of a fantastically immense communications web reaching into every nook and cranny of every developed country.

Then modems came along and turned the tables. Modems are a digital hack on an analog technology, of course; they take the digits from your computer and convert them into a complicated analog waveform that can be transmitted down existing wires. The roar of white noise that you hear when you listen in on a modem transmission is exactly what Bell was originally aiming for with his reeds. Modems, and everything that has ensued from them, like the World Wide Web, are just the latest example of a pattern that was established by Kelvin 140 years ago, namely, hacking existing wires by inventing new stuff to put on the ends of them.

It is natural, then, to ask what effect FLAG is going to have on the latest and greatest cable hack: the Internet. Or perhaps it's better to ask whether the Internet affected FLAG. The explosion of the Web happened after FLAG was planned. Taketo Furuhata, president and CEO of IDC, which runs the Miura station, says: "I don't know whether Nynex management foresaw the burst of demand related to the Internet a few years ago—I don't think so. Nobody—not even AT&T people—foresaw this. But the demand for Internet transmission is so huge that FLAG will certainly become a very important pipe to transmit such requirements."

John Mercogliano, vice president—Europe, Nynex Network Systems (Bermuda) Ltd., says that during the early 1990s when FLAG was getting organized, Nynex executives felt in their guts that something big was going to happen involving broadband multimedia transmission over cables. They had a media lab that was giving demos of medical imaging and other such applications. "We knew the Internet was coming—we just didn't know it was going to be called the Internet," he says.

FLAG may, in fact, be the last big cable system that was planned in the days when people didn't know about the Internet. Those days were a lot calmer in the global telecom industry. Everything was controlled by monopolies, and cable construction was based on sober, scientific forecasts, analogous, in some ways, to the actuarial tables on which insurance companies predicate their policies.

When you talk on the phone, your words are converted into bits that are sent down a wire. When you surf the Web, your computer sends out bits that ask for yet more bits to be sent back. When you go to the store and buy a Japanese VCR or an article of clothing with a Made in Thailand label, you're touching off a cascade of information flows that eventually leads to transpacific faxes, phone calls, and money transfers.

If you get a fast busy signal when you dial your phone, or if your Web browser stalls, or if the electronics store is always low on inventory because the distribution system is balled up somewhere, then it means that someone, somewhere, is suffering pain. Eventually this pain gets taken out on a fairly small number of meek, mild-mannered statisticians—telecom traffic forecasters—who are supposed to see these problems coming.

Like many other telephony-related technologies, traffic forecasting was developed to a fine art a long time ago and rarely screwed up. Usually the telcos knew when the capacity of their systems was going to be stretched past acceptable limits. Then they went shopping for bandwidth. Cables got built.

That is all past history. "The telecoms aren't forecasting now," Mercogliano says. "They're reacting."

This is a big problem for a few different reasons. One is that cables take a few years to build, and, once built, last for a quarter of a century. It's not a nimble industry in that way. A PTT thinking about investing in a club cable is making a 25-year commitment to a piece of equipment that will almost certainly be obsolete long before it reaches the end of its working life. Not only are they risking lots of money, but they are putting it into an exceptionally long-term investment. Long-term investments are great if you have reliable long-term forecasts, but when your entire forecasting system gets blown out of the water by something like the Internet, the situation gets awfully complicated.

The Internet poses another problem for telcos by being asymmetrical. Imagine you are running an international telecom company in Japan. Everything you've ever done, since TPC-1 came into Ninomiya in '64, has been predicated on circuits. Circuits are the basic unit you buy and sell—they are to you what cars are to a Cadillac dealership. A circuit, by definition, is symmetrical. It consists of an equal amount of bandwidth in each direction—since most phone conversations, on average, entail both parties talking about the same amount. A circuit between Japan and the United States is something that enables data to be sent from Japan to the US, and from the US to Japan, at the same rate—the same bandwidth. In order to get your hands on a circuit, you cut a deal with a company in the States. This deal is called a correspondent agreement.

One day, you see an ad in a magazine for a newfangled thing called a modem. You hook one end up to a computer and the other end to a phone line, and it enables the computer to grab a circuit and exchange data with some other computer with a modem. So far, so good. As a cable-savvy type, you know that people have been hacking cables in this fashion since Kelvin. As long as the thing works on the basis of circuits, you don't care—any more than a car salesman would care if someone bought Cadillacs, tore out the seats, and used them to haul gravel.

A few years later, you hear about some modem-related nonsense called the World Wide Web. And a year after that, everyone seems to be talking about it. About the same time, all of your traffic forecasts go down the toilet. Nothing's working the way it used to. Everything is screwed up.

Why? Because the Web is asymmetrical. All of your Japanese Web customers are using it to access sites in the States, because that's where all the sites are located. When one of them clicks on a button on an American Web page, a request is sent over the cable to the US. The request is infinitesimal, just a few bytes. The site in the States promptly responds by trying to send back a high-resolution, 24-bit color image of Cindy Crawford, or an MPEG film of a space shuttle mission. Millions of bytes. Your pipe gets jammed solid with incoming packets.

You're a businessperson. You want to make your customers happy. You want them to get their millions of bytes from the States in some reasonable amount of time. The only way to make this happen is to purchase more circuits on the cables linking Japan to the States. But if you do this, only half of each circuit is going to be used—the incoming half. The outgoing half will carry a miserable trickle of packets. Its bandwidth will be wasted. The correspondent agreement relationship, which has been the basis of the international telecom business ever since the first cables were laid, doesn't work anymore.

This, in combination with the havoc increasingly being wrought by callback services, is weird, bad, hairy news for the telecom monopolies. Mercogliano believes that the solution lies in some sort of bandwidth arbitrage scheme, but talking about that to an old-time telecrat is like describing derivative investments to an old codger who keeps his money under his mattress. "The club system is breaking down," Mercogliano says.

Somewhere between50° 54.20062' N, 1° 26.87229 W and50° 54.20675' N, 1° 26.95470 WCable Ship Monarch, Southampton, England

John Mercogliano, if this is conceivable, logs even more frequent-flier miles, to even more parts of the planet, than the cable layers we met on Lan Tao Island. He lives in London, his office is in Amsterdam, his territory is Europe, he works for a company headquartered in Bermuda that has many ties to the New York metropolitan area and that does business everywhere from Porthcurno to Miura. He is trim, young-looking, and vigorous, but even so the schedule occasionally takes its toll on him, and he feels the need to just get away from his job for a few days and think about something—anything—other than submarine cables. The last time this feeling came over him, he made inquiries with a tourist bureau in Ireland that referred him to a quiet, out-of-the-way place on the coast: a stately home that had been converted to a seaside inn, an ideal place for him to go to get his mind off his work. Mercogliano flew to Ireland and made his way overland to the place, checked into his room, and began ambling through the building. The first thing he saw was a display case containing samples of various types of 19th-century submarine cables. It turned out that the former owner of this mansion had been the captain of the **Great Eastern**, the first of the great deep-sea cable-laying ships.

The **Great Eastern** got that job because it was by a long chalk the largest ship on the planet at the time—so large that its utter uselessness had made it a laughingstock, the **Spruce Goose** of its day. The second generation of long-range submarine cables, designed to Lord Kelvin's specifications after the debacle of 1857, were thick and heavy. Splicing segments together in mid-ocean had turned out to be problematical, so there were good reasons for wanting to make the cable in one huge piece and simply laying the whole thing in one go.

It is easier to splice cables now and getting easier all the time. Coaxial cables of the last few decades took some 36 to 48 hours to splice, partly because it was necessary to mold a jacket around them. Modern cables can be spliced in more like 12 hours, depending on the number of fibers they contain. So modern cable ships needn't be quite as great as the **Great Eastern**.

Other than the tank that contains the cable, which is literally nothing more than a big round hole in the middle of the ship, a cable ship is different from other ships in two ways. One, it comes with a complement of bow and stern thrusters coupled to exquisitely sensitive navigation gear on the bridge, which give it unsurpassed precision-maneuvering and station-keeping powers. In the case of **Monarch**, a smaller cable repair ship that we visited in Southampton, England, there are at least two differential GPS receivers, one for the bow and one for the stern—hence the two readings given at the head of this section. Each one of them reads out to five decimal places, which implies a resolution of about 1 centimeter.

Second, a cable ship has two winches on board. But this does not do justice to them, as they are so enormous, so powerful, and yet so nimble that it would almost be more accurate to say that a cable ship **is** two floating winches. Nearly everything that a cable ship does reduces, eventually, to winching. Laying a cable is a matter of paying cable out of a winch, and repairing it, as already described, involves a much more complicated series of winch-related activities.

As Kelvin figured out the hard way, whenever you are reeling in a long line, you must first relieve all tension on it or else your reel will be crushed. The same problem is posed in reverse by the cable-laying process, where thousands of meters of cable, weighing many tons, may be stretched tight between the ship and the contact point on the seafloor, but the rest of the cable stored on board the ship must be coiled loosely in the tanks with no tension on them at all. In both cases, the cable must be perfectly slack on the ship end and very tight on the watery end of the winching machinery. Not surprisingly, then, the same machinery is used for both outgoing and incoming winch work.

At one end of the ship is a huge iron drum some 3 meters in diameter with a few turns of cable around it. As you can verify by wrapping a few turns of rope around a pipe and tugging, this is a very simple way to relieve tension on a line. It is not, however, very precise, and here, precise control is very important. That is provided by something called a linear engine, which consists of several pairs of tires mounted with a narrow gap between them (for you baseball fans, it is much like a pitching machine). The cable is threaded through this gap so that it is gripped on both sides by the tires. **Monarch**'s linear engine contains 16 pairs of tires which, taken together, can provide up to 10 tons of holdback force. Augmented by the drums, which can be driven by power from the ship's main engines, the ultimate capacity of **Monarch**'s cable engines is 30 tons.

The art of laying a submarine cable is the art of using all the special features of such a ship: the linear engines, the maneuvering thrusters, and the differential GPS equipment, to put the cable exactly where it is supposed to go. Though the survey team has examined a corridor many thousands of meters wide, the target corridor for the cable lay is 200 meters wide, and the masters of these ships take pride in not straying more than 10 meters from the charted route. This must be accomplished through the judicious manipulation of only a few variables: the ship's position and speed (which are controlled by the engines, thrusters, and rudder) andthe cable's tension and rate of payout (which are controlled by the cable engine).

One cannot merely pay the cable out at the same speed as the ship moves forward. If the bottom is sloping down and away from the ship as the ship proceeds, it is necessary to pay the cable out faster. If the bottom is sloping up toward the ship, the cable must come out more slowly . Such calculations are greatly complicated by the fact that the cable is stretched out far behind the ship—the distance between the ship and the cable's contact point on the bottom of the ocean can be more than 30 kilometers, and the maximum depth at which (for example) KDD cable can be laid is 8,000 meters. Insofar as the shape of the bottom affects what the ship ought to be doing, it's not the shape of the bottom directly below the ship that is relevant, but the shape of the bottom wherever the contact point happens to be located, which is by no means a straightforward calculation. Of course, the ship is heaving up and down on the ocean and probably being shoved around by wind and currents while all this is happening, and there is also the possibility of ocean currents that may move the cable to and fro during its descent.

It is not, in other words, a seat-of-the-pants kind of deal; the skipper can't just sit up on the bridge, eyeballing a chart, and twiddling a few controls according to his intuition. In practice, the only way to ensure that the cable ends up where it is supposed to is to calculate the whole thing ahead of time. Just as aeronautical engineers create numerical simulations of hypothetical airplanes to test their coefficient of drag, so do the slack control wizards of Cable & Wireless Marine use numerical simulation techniques to model the catenary curve adopted by the cable as it stretches between ship and contact point. In combination with their detailed data on the shape of the ocean floor, this enables them to figure out, in advance, exactly what the ship should do when. All of it is boiled down into a set of instructions that is turned over to the master of the cable ship: at such and such a point, increase speed to **x** knots and reduce cable tension to **y** tons and change payout speed to **z** meters per second, and so on and so forth, all the way from Porthcurno to Miura."

It sounds like it would make a good videogame," I said to Captain Stuart Evans after he had laid all of this out for me. I was envisioning something called SimCable. "It would make a good videogame," he agreed, "but it also makes a great job, because it's a combination of art and science and technique —and it's not an art you learn overnight. It's definitely a black art."

Cable & Wireless's Marine Survey department has nailed the slack control problem. That, in combination with the company's fleet of cable-laying ships and its human capital, makes it dominant in the submarine cable-laying world.

By "human capital" I mean their ability to dispatch weather-beaten operatives such as the Lan Tao Island crowd to difficult places like Suez and have them know their asses from their elbows. As we discovered on our little jaunt to Egypt, where we tried to rendezvous with a cable ship in the Gulf of Suez and were turned back by the Egyptian military, one doesn't just waltz into places like that on short notice and get stuff to happen.

In each country between England and Japan, there are hoops that must be jumped through, cultural differences that must be understood, palms that must be greased, unwritten rules that must be respected. The only way to learn that stuff is to devote a career to it. Cable & Wireless has an institutional memory stretching all the way back to 1870, when it laid the first cable from Porthcurno to Australia, and the British maritime industry as a whole possesses a vast fund of practical experience that is the legacy of the Empire.

One can argue that, in the end, the British Empire did Britain surprisingly little good. Other European countries that had pathetic or nonexistent empires, such as Italy, have recently surpassed England in standard of living and other measures of economic well-being. Scholars of economic history have worked up numbers suggesting that Britain spent more on maintaining its empire than it gained from exploiting it. Whether or not this is the case, it is quite obvious from looking at the cable-laying industry that the Victorian practice of sending British people all over the planet is now paying them back handsomely.

The current position of AT&T versus Cable & Wireless reflects the shape of America versus the shape of the British Empire. America is a big, contiguous mass, easy to defend, immensely wealthy, and basically insular. No one comes close to it in developing new technologies, and AT&T has always been one of America's technological leaders. By contrast, the British Empire was spread out all over the place, and though it controlled a few big areas (such as India and Australia), it was basically an archipelago of outposts, let us say a network, completely dependent on shipping and communications to stay alive. Its dominance was always more economic than military—even at the height of the Victorian era, its army was smaller than the Prussian police force. It could coerce the natives, but only so far—in the end, it had to co-opt them, give them some incentive to play along. Even though the Empire has been dissolving itself for half a century, British people and British institutions still know how to get things done everywhere.

It is not difficult to work out how all of this has informed the development of the submarine cable industry. AT&T makes really, really good cables; it has the pure technology nailed, though if it doesn't stay on its toes, it'll be flattened by the Japanese. Cable & Wireless doesn't even try to make cables, but it installs them better than anyone else.

The legacy

Kelvin founded the cable industry by understanding the science, and developing the technology, that made it work. His legacy is the ongoing domination of the cable-laying industry by the British, and his monument is concealed beneath the waves: the ever growing web of submarine cables joining continents together.

Bell founded the telephone industry. His legacy was the Bell System, and his monument was strung up on poles for all to see: the network of telephone wires that eventually found its way into virtually every building in the developed world. Bell founded New England Telephone Company, which eventually was absorbed into the Bell System. It never completely lost its identity, though, and it never forgot its connection to Alexander Graham Bell—it even moved Bell's laboratory into its corporate headquarters in Boston.

After the breakup of the Bell System in the early 1980s, New England Telephone and its sibling Baby Bell, New York Telephone, joined together to form a new company called Nynex, whose loyal soldiers are eager to make it clear that they see themselves as the true heirs of Bell's legacy. Now, Nynex and Cable & Wireless, the brainchildren of Bell and Kelvin, the two supreme ninja hacker mage lords of global telecommunications, have formed an alliance to challenge AT&T and all the other old monopolies.

We know how the first two acts of the story are going to go: In late 1997, with the completion of FLAG, Luke ("Nynex") Skywalker, backed up on his Oedipal quest by the heavy shipping iron of Han ("Cable & Wireless") Solo, will drop a bomb down the Death Star's ventilation shaft. In 1999, with the completion of SEA-ME-WE 3, the Empire will Strike Back. There is talk of a FLAG 2, which might represent some kind of a **Return of the Jedi** scenario.

But once the first FLAG has been built, everyone's going to get into the act—it's going to lead to a general rebellion. "FLAG will change the way things are done. They are setting a benchmark," says Dave Handley, the cable layer. And Mercogliano makes a persuasive case that national telecom monopolies will be so preoccupied, over the next decade, with building the "last mile" and getting their acts together in a competitive environment that they'll have no choice but to leave cable laying to the entrepreneurs.

That's the simple view of what FLAG represents. It is important to remember, though, that companies like Cable & Wireless and Nynex are not really heroic antimonopolists. A victory for FLAG doesn't lead to a pat ending like in **Star Wars**—it does not get us into an idealized free market. "One thing to bear in mind is that Cable & Wireless **is** a club and they are rigorously anticompetitive wherever they have the opportunity," said Doug Barnes, the cypherpunk. "Nynex and the other Baby Bells are self-righteously trying to crack open other companies' monopolies while simultaneously trying to hold onto their domestic ones. The FLAG folks are merely clubs with a smidgin more vision, enough business sense to properly reward talent, and a profound desire to make a great pile of money."

There has been a lot of fuss in the last few years concerning the 50th anniversary of the invention of the computer. Debates have raged over who invented the computer: Atanasoff or Mauchly or Turing? The only thing that has been demonstrated is that, depending on how you define **computer**, any one of the above, and several others besides, can be said to have invented it.

Oddly enough, this debate comes at a time when stand-alone computers are seeming less and less significant and the Internet more so. Whether or not you agree that "the network is the computer," a phrase Scott McNealy of Sun Microsystems recently coined, you can't dispute that moving information around seems to have much broader appeal than processing it. Many more people are interested in email and the Web than were interested in databases and spreadsheets.

Yet little attention has been paid to the historical antecedents of the Internet—perhaps partly because these cable technologies are much older and less accessible and partly because many Net people want so badly to believe that the Net is fundamentally new and unique. Analog is seen as old and bad, and so many people assume that the communications systems of old were strictly analog and have just now been upgraded to digital.

This overlooks much history and totally misconstrues the technology. The first cables carried telegraphy, which is as purely digital as anything that goes on inside your computer. The cables were designed that way because the hackers of a century and a half ago understood perfectly well why digital was better. A single bit of code passing down a wire from Porthcurno to the Azores was apt to be in sorry shape by the time it arrived, but precisely because it was a bit, it could easily be abstracted from the noise, then recognized, regenerated, and transmitted anew.

The world has actually been wired together by digital communications systems for a century and a half. Nothing that has happened during that time compares in its impact to the first exchange of messages between Queen Victoria and President Buchanan in 1858. That was so impressive that a mob of celebrants poured into the streets of New York and set fire to City Hall.

It's tempting to observe that, so far, no one has gotten sufficiently excited over a hot new Web page to go out and burn down a major building. But this is a little too glib. True, that mob in the streets of New York in 1858 was celebrating the ability to send messages quickly across the Atlantic. But, if the network is the computer, then in retrospect, those torch-bearing New Yorkers could be seen as celebrating the joining of the small and primitive computer that was the North American telegraph system to the small and primitive computer that was the European system, to form The Computer, with a capital C.

At that time, the most important components of these Computers—the CPUs, as it were—were tense young men in starched collars. Whenever one of them stepped out to relieve himself, The Computer went down. As good as they were at their jobs, they could process bits only so fast, so The Computer was very slow. But The Computer has done nothing since then but get faster, become more automated, and expand. By 1870, it stretched all the way to Australia. The advent of analog telephony plunged The Computer into a long dormant phase during which it grew immensely but lost many of its computerlike characteristics.

But now The Computer is fully digital once again, fully automatic, and faster than hell. Most of it is in the United States, because the United States is large, free, and made of dirt. Largeness eliminates troublesome borders. Freeness means that anyone is allowed to patch new circuits onto The Computer. Dirt makes it possible for anyone with a backhoe to get in on the game. The Computer is striving mightily to grow beyond the borders of the United States, into a world that promises even vaster economies of scale—but most of that world isn't made of dirt, and most of it isn't free. The lack of freedom stems both from bad laws, which are grudgingly giving way to deregulation, and from monopolies willing to do all manner of unsavory things in order to protect their turf.

Even though FLAG's bandwidth isn't that great by 1996 Internet standards, and even though some of the companies involved in it are, in other arenas, guilty of monopolistic behavior, FLAG really is going to help blow open bandwidth and weaken the telecom monopolies.

In many ways it hearkens back to the wild early days of the cable business. The first transatlantic cables, after all, were constructed by private investors who, like FLAG's investors, just went out and built cable because it seemed like a good idea. After FLAG, building new high-bandwidth, third-generation fiber-optic cable is going to seem like a good idea to a lot of other investors. And unlike the ones who built FLAG, they will have the benefit of knowing about the Internet, and perhaps of understanding, at some level, that they are not merely stringing fancy telephone lines but laying down new traces on the circuit board of The Computer. That understanding may lead them to create vast amounts of bandwidth that would blow the minds of the entrenched telecrats and to adopt business models designed around packet-switching instead of the circuits that the telecrats are stuck on.

If the network is The Computer, then its motherboard is the crust of Planet Earth. This may be the single biggest drag on the growth of The Computer, because Mother Earth was not designed to be a motherboard. There is too much water and not enough dirt. Water favors a few companies that know how to lay cable and have the ships to do it. Those companies are about to make a whole lot of money.

Eventually, though, new ships will be built. The art of slack control will become common knowledge—after all, it comes down to a numerical simulation problem, which should not be a big chore for the ever-expanding Computer. The floors of the oceans will be surveyed and sidescanned down to every last sand ripple and anchor scar. The physical challenges, in other words, will only get easier.

The one challenge that will then stand in the way of The Computer will be the cultural barriers that have always hindered cooperation between different peoples. As the globe-trotting cable layers in Papa Doc's demonstrate, there will always be a niche for people who have gone out and traveled the world and learned a thing or two about its ways.

Hackers with ambitions of getting involved in the future expansion of The Computer could do a lot worse than to power down their PCs, buy GPS receivers, place calls to their favorite travel agents, and devote some time to the pursuit of hacker tourism.

The motherboard awaits.

#MAGAZINE-4.12

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