parts, but there is a real question of whether a 'me too' strategy will work," scoffs one Silicon Valley executive.

None of these dire warnings troubles Inmos executives, however. They are counting on two factors to ensure success. The first is the fact that because Inmos is a brand-new company, it will be using the latest production technologies, which should ensure higher quality products with less wastage. Established companies, Petritz argues, are likely to phase in new production technologies more slowly in order to get maximum use out of their existing equipment. And the second factor is that Inmos believes its memory chips are technically superior to those of its competitors. "We have the part that the industry has been waiting for," claims David Wooten, who helped develop it.

Inmos's 64K RAM will not be in mass production until later this year, but test models have already proved to be faster—that is, data can be retrieved from them more quickly—than the memory chips produced by other companies. Moreover, Inmos officials believe that the company's technical competence has already been demonstrated with its first product, a 16K "static" RAM that it has just begun to produce in bulk. Unlike the standard 16K "dynamic" RAM, this device holds data without having to be continually recharged, and it is also much faster. But its high price will restrict its market mostly to large, mainframe computers. Even Inmos's competitors agree that its 16K static RAM is a well-designed and engineered product.

In backing Inmos, the British government has taken a far bolder and riskier approach than its European counterparts. The French government, for example, is encouraging French companies to enter joint ventures with American microelectronics firms, and most European nations are keen for U.S. and Japanese companies to establish production facilities on their soil.

> "There is going to be a brutal price war and a start-up company is not going to stand a chance."

As for Inmos's financial viability, Richard Hall, the company's vice president for finance and administration, believes that the venture will begin to show an annual profit by 1983. In that year, the Bristol group's microprocessor should enter the market. Petritz is even more optimistic. He predicts that Inmos will achieve a turnover of $500 million by the mid-1980's.

The real test of Inmos's success will come in a few years time, when the British government will either sell off the venture to private industry or allow it to go public by selling shares on the stock exchange. At that point it will be clear whether Britain has managed to establish a viable microelectronics enterprise with its bold transatlantic gamble.

—COLIN NORMAN

ELF Resurrected After Drowning by Navy

Admirals caught playing budget games with important strategic system

Rarely do military chiefs get in trouble for failing to spend money on new equipment. But that is what happened to the Navy's highest officials this spring as they were drawing up the new budget. They were reversed by the Administration after dumping a project known as ELF, an Extremely Low Frequency communications system to be used for issuing orders to missile-carrying submarines. The sudden abandonment of ELF was peculiar because for a decade the Navy had insisted the system was essential.

Defense Secretary Caspar Weinberger and some White House staffers so disagreed with what the admirals did to ELF that they persuaded the President to step in and straighten things out. On 10 April Reagan commanded the Department of Defense (DOD) to save ELF, to provide $34.8 million for it in the budget (the latest appropriation before this was for $2.7 million in 1979), and report back in August with a complete study of the system's value.

The Navy's motives are unknown. The prevailing theory in the defense community, however, is that the admirals were trying a familiar budget game. Knowing that ELF had some strong support in Congress, they decided to put their efforts into getting new airplanes and let others make the case for the unpopular old ELF.

In the struggle for survival, ELF has gone through many transformations since its inception in the early 1960's. The main reason: people were scared by its size, for it required a huge antenna. The arms of the antenna in the Navy's original plan would have been 6000 miles long; they were intended to carry a large electrical charge; and they were to be buried in long, unfenced strips of land. These strips would have cut across farms, woods, and parks and would have embraced 41 percent of the state of Wisconsin. Many people worried as well that the antenna lines would produce unexpected health hazards or drive down property values. These concerns made an orphan of ELF. Governors and congressmen from the states in which the Navy would like to build ELF understandably stalled work on the project and caused the Navy to whittle down the dimensions (*Science*, 2 September 1977, p. 964).

It has been scaled down drastically in recent designs. The antenna in the latest version of the scheme, sometimes called the austere ELF, would require only 5 percent as much land as the one originally designed by the Navy. The full-scale version was so large that the Navy had a hard time finding a place for it. ELF's home has shifted from Wisconsin to Texas, then to Michigan, and back to Wis-

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consin. Its name has changed, too: from Sanguine to Seafarer to ELF. The oddest part of the story is the latest, however. After telling the public for more than a decade that this unwelcome project was absolutely essential, the Navy suddenly decided to drop it from the budget in February, at a time when the outlook for ELF was the best it had ever been. The Navy's reversal, several congressmen pointed out, could damage its ability to argue for other expensive projects. One reason the Administration may have stepped in to save ELF is that it may have been necessary to preserve the Pentagon's credibility.

ELF would provide a radio link between commanders on shore and submarines deep in the ocean. Unlike any other system available now or foreseeable in this decade, it would make it possible to send messages to submarines at their usual operating depth. America's submarines now get their orders by coming to the surface or by approaching the surface and sending up a buoyant antenna. Ordinary (high frequency) radio broadcasts cannot penetrate the ocean, so the Navy developed a special low frequency system to reach underwater receivers. The lower a wave's frequency, the better it penetrates. Very low frequency broadcasts (14 to 30 kilohertz) are used for communicating with subs today, but these signals only reach depths of 10 to 15 meters. ELF signals in the 72- to 80-hertz range would penetrate more than 100 meters of water.

The problem with current radio systems is that they require the ship to rise for messages, thereby risking detection. Any technology that made this unnecessary would be valuable not just for protecting the submarine fleet, but for maintaining the balance of terror between the nuclear powers. The missiles carried on submarines are now the strongest deterrent against a surprise nuclear attack, because the submarines would survive any conceivable first strike. Anything that increases the likelihood of their survival makes nuclear war in theory less likely. That theoretical value did not outweigh the intensity of local opposition. Three Presidents—Nixon, Ford, and Carter—acceded to local requests not to build ELF.

Thus the Reagan Administration inherited a much diminished version of the project when it came into office. A small test antenna about 30 miles long has been built in Clam Lake, Wisconsin. Because President Carter would not give his endorsement, the Pentagon was prevented from spending even the money that had been appropriated for Clam Lake. The funds ran out in 1978, and the experimental center was closed in January of 1979.

In what the Navy calls the austere version, it has proposed to experiment with a mini-ELF by linking the antenna at Clam Lake with a slightly larger one (130 miles long) to be built at K. I. Sawyer Air Force Base in upper Michigan. This arrangement would make it possible to send short messages to deeply submerged vessels in some but not all important areas. It would also provide valuable data. Presumably, if the data were favorable, this little project would help win the Navy some support for its dream version of ELF. Alternatively, bad results from this small test could save the Navy great potential cost and embarrassment. Finally, skeptics could learn by experience what it is like to live near buried ELF wires.

Despite these considerations, the Navy did not seize the opportunity to get ELF started in the new Administration. Navy officials, including the one most directly responsible, the Chief of Naval Operations, Admiral Thomas Hayward, decline to discuss the subject now. But others involved in the controversy give accounts of what happened in terms that are consistent and credible. Among those who supplied the details are aides for Senators Gordon Humphrey (R–N.H.), Carl Levin (D–Mich.), and John Tower (R–Texas), several defense contractors, and a Carter Administration defense official.

Although the Navy wanted to build the ELF, several admirals preparing the 1982 budget request apparently decided that they would rather press Congress this year for some new aircraft for the TACAMO system. The latter is a relay that takes messages from shore bases and retransmits them to submarines at shallow depth in the ocean. These planes are getting old and need refurbishing or replacement, if the system is to be kept up. The admirals recommended that ELF be left in a "caretaker status," neither expanded nor closed for good. In effect, they said ELF was not as important as the Navy had claimed for the previous 10 years. Their budget recommendation was approved by Hayward and by the under secretary of the Navy. The Secretary, John Lehman, took himself out of the matter because he thought he might have a business conflict.

News of the decision not to expand ELF leaked to Senator Levin, who as a Michigan Democrat had opposed the project. He spread the word and, according to one observer, "tried to make it a fait accompli." Veterans organizations, local officials in Michigan and Wisconsin, and others who had campaigned loyally over the years for ELF suddenly felt betrayed. They wrote to Reagan, Weinberger, and Hayward. The furor was not calmed until Weinberger huddled with Reagan and agreed that the President would order the Navy to reopen the Clam Lake site, fund ELF, and write a report.

Certainly no technical study in the last few years or months has found the ELF concept deficient. A review by the National Academy of Sciences (NAS) concluded in 1977 that the dangers it poses to humans and wildlife are slight, although the NAS group did mention several areas that needed more research, presumably at a site like Clam Lake. Finally, the key official who reviewed this issue for the Carter Administration says ELF is the only feasible means for communicating with submarines at operating depth. He knows this is so because he tried to find another. He says, "We looked at anything that would jiggle the environment in any way, lasers, acoustical signals, everything." Carter was under pressure from Michigan Democrats not to endorse ELF, and any technician who could have produced a working alternative would have been a hero. But Carter's staff found no alternatives. The Carter official was preparing to "make another run at the President" after the election to recommend building ELF. He did not get the opportunity.

Carter was under pressure not to endorse ELF, and any technician who could have produced a working alternative would have been a hero.

The lessons in this tale are not so remarkable: common sense does not prevail, the direct approach is underused, and one of the biggest obstacles the military must contend with regularly is a clumsy leadership.

—ELIOT MARSHALL