cess in translating its technical mastery into hard cash is still far from assured. Its prime asset, a corps of able researchers and technicians, may count for less than marketing skills or fermentation technology when the art of gene splicing becomes more generally available.

On the other hand, the skills shown by Genentech's scientists and managers so far may enable it to stay atop the crest of the wave and continue to dominate the growing industry. In which case the Street's first reaction to Genentech's stock may not have been totally off the wall.—NICHOLAS WADE

Iraqi Nuclear Program Halted by Bombing

The air attack missed Iraq's reactors, but raised a specter of conventional war with radioactive fallout

The battered French program to build a nuclear research center for Iraq was hit with a new setback this fall just after radioactive fuel had been delivered for installation. Bombs, presumably delivered by Iranian pilots, hit the research site about 10 miles from the center of Baghdad on 30 September. They damaged an auxiliary building and forced the French technicians working on the project to leave. The attack did not damage the reactors, but it did shut down the program indefinitely.

The incident provoked speculation of two kinds: on the specific effects of this air raid and on the general risks that war presents to operators of nuclear plants.

The Iraqi center, called Tuwaitha, included a small Soviet research reactor (5 megawatts in thermal power) built in the 1960's, a new French reactor known as Osirak (about 50 megawatts), and a full-scale mock-up of the Osirak called Isis (only about 800 kilowatts). The French reactors are duplicates of a reactor in Saclay, France, incorporating the latest research technology. France has also offered to build a large (900-megawatt) power reactor for Iraq sometime in the future. Bids are now being entertained.

Coming on the heels of two other acts of sabotage, the attack on Tuwaitha seemed to some observers part of a larger plot. In 1979 part of the Osirak core was damaged by a bomb while being shipped from the factory in Toulon, France. Then in June of this year, the Egyptian physicist serving as the chief liaison between France and Iraq was murdered in a hotel room in Paris (*Science*, 29 August). The French press did not hesitate to report the widespread suspicion that these were the acts of Israeli saboteurs.

Thus, the weekly journal *L'Express* asked in a major article on 11 October, "Qui a Bombardé Osirak?" Its answer: western specialists confirm that it could be no one but Israel. The only evidence the journal cited was the word of "one of the most qualified sources" that this was the conclusion of several European intelligence agencies.

Israel denied that it had had any part in the business. It is true, however, that the chief of Israeli military intelligence appeared on television 2 days before the attack, wondering aloud why the Iranians had neglected to bomb the Iraqi atomic site.

The Israelis have protested France's decision to supply nuclear technology to Iraq ever since the announcement of a contract in 1976. From a legal point of view, they have little to work with, for the Iraqis and the French have followed to the letter all the safety and nonproliferation requirements of the International Atomic Energy Agency. Likewise, Iraq has signed the Nuclear Nonproliferation Treaty. Israel and France have not.

Israel fears that Iraq will use its newly acquired machinery to build the first Arab bomb, or—nearly as objectionable—to train a generation of nuclear physicists who will later build weapons for the Arab world. Israel has a motive for destroying Osirak, but no one has found Israelis at the scene of any of the crimes.

The French authorities prefer to say as little as possible about the work in Iraq, on the grounds that the documents are strictly confidential. The French are embarrassed by the furor that surrounds the project, and, as one official of the Commisariat à l'Energie Atomique (CEA) explained, giving out further information would only revive the campaign against Osirak which has been "all over the press." Thus it is impossible to learn from an official source what happened to the Iraqi reactor. But the CEA does not contradict reports which have appeared in the French press, saying the damage was negligible, and that some fuel is already at the site.

The mock-up reactor, Isis, was apparently due to receive its first charge of fuel (93 percent enriched uranium) in the week before the Iraqi-Iranian war broke out. Twelve to 13 kilograms of uranium fuel have been delivered, according to French accounts. Loading was postponed and then abandoned following the air raid. Some French workers are still at the site, but they remain only to help with maintenance and protection of the site. The program, which counted on starting the reactors in 1981, has been delayed by a year or two. A new furor is brewing in France over the fact that the highly enriched uranium has now been left in Iraqi hands without proper French supervision. The French government is divided on how to proceed with the plan.

If the attackers had scored a direct hit on a loaded Osirak, would they have created a radioactive disaster in Iraq? The CEA spokesman, Jean Pellerin, would not discuss the plant's design, but said it was a copy of a reactor at Saclay which is protected by a concrete containment structure. The containment on large power reactors—in France as in the United States and Germany—is made of steel-reinforced concrete, several feet thick. It is intended to prevent the release of radioactive debris from an accident, but is also made to withstand the impact of a large commercial jetliner. Osirak, a rather large research reactor, does not have as massive a shield as a power reactor. But according to one expert at the American Department of Energy (DOE), it contains a concrete "biological shield" at least a meter thick.

In order to do serious damage, a bomb would have to penetrate the building that houses Osirak, Osirak's concrete shield (or, if from the right angle, a deep pool of water), and finally the metal vessel which holds the fuel. Most conventional weapons could not do this, although a large electronically guided "smart" bomb of the kind used by the U.S. Air

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L'Agence Sigma Photo

A shopping trip to France

Former Prime Minister Jacques Chirac, left, shows nuclear wares to Iraqi strong man Saddam Hussein.

Force in Vietnam might do so. Specially designed penetrating weapons might succeed in hitting the core, but these are not available to most warmakers.

A reactor specialist in the international affairs office of DOE said that he understood the fuel now in Iraq is intended for Isis and not Osirak. He said as well that the fuel assembly would be a difficult target to hit from the air, since its cross section is about the size of a hand. Steve Ramos, an official at the Nuclear Regulatory Commission who formerly directed the safety program for U.S. research reactors, agreed that there was very little risk that bombing a research reactor would ever cause a significant fallout problem. In the worst conceivable scenario, he could not envision radioactive pollution traveling beyond a mile or two from the reactor.

The federal government has given little thought to the special hazards that nuclear plants pose in wartime. Probably the best available published review of the subject came out in August: *Destruction of Nuclear Energy Facilities in War* by Bennett Ramberg, a research fellow at the Center for International and Strategic Affairs at the University of California at Los Angeles. Ramberg does not include research reactors in his study, for the risks they pose are so slight. He focuses on large electricity-generating reactors, which are typically 20 to 100 times more powerful. These could become attractive military targets, Ramberg believes, because they are becoming important in some nations' industrial economies.

There are no power reactors operating at the moment in the Middle East. As a rule, the biggest plants are located today in the nations with the most stable political systems. This stability may not last. Egypt, Israel, Iraq, and Libya all plan to build power reactors in the 1980's. (Since the overthrow of the Shah, Iran has canceled its nuclear construction contracts, permanently ending its ambitious nuclear program.) India, Pakistan, South Africa, South Korea, Taiwan, and the Republic of China now operate or are planning to build power reactors. All have belligerent neighbors. In most of these countries, the reactors pose no special wartime threat to their owners because they are located far from major cities. But Ramberg points out that Israel will be at risk no matter where it puts its reactor because it is such a small country. Egypt will build its first reactor not far from the city of Alexandria, where Ramberg estimates that tens of thousands of people could be affected by fallout in a worst-case bombing scenario. India's reactors also are located near populous areas.

Ramberg's survey suggests a few general conclusions about the hazards of owning a reactor in wartime. First, reactors present no special risk in the context of war among the superpowers. These nations presumably defend themselves with nuclear weapons, and a belligerent using nuclear weapons hardly adds anything to the radioactive damage already inflicted by striking at nuclear targets. Second, little of strategic worth is gained by hitting research reactors—whether they are owned by superpowers or small nations. It would require a well-organized and well-armed attack to make a direct hit on a research reactor, making this a particularly costly proposal. Finally, there is one important category of risk to be considered: a war among lesser nations leading to a conventional attack on a power reactor or large power fuel storage site. If it were well planned, such an attack could spread radioactive fallout over a large area and, with proper weather conditions, carry the damage across numerous national borders. The worst effects would be contained, Ramberg calculates, within an area 15 to 40 miles downwind of the reactor. But long-term effects might be felt hundreds of miles away.

Fortunately, the countries least able to defend against such an attack today also lack the power reactors that might need defending. But the situation is changing. It may not be long before the world includes nations with the will, the weapons, and the vulnerabilities to brew up a conventional/radioactive war.

—ELIOT MARSHALL