



## In the Line of Fire

The question on everyone's mind at a recent meeting of scientists and sponsors was literally: How do we survive?

**AMMAN**—Wissam Al-Hashimi, a senior geologist with Iraq's Ministry of Oil and vice president of the Arab Geologists Association, was looking forward to coming to Jordan for a conference on Iraqi science. Then the grim reality of Baghdad intervened: Late last month, the British-educated scientist was kidnapped from his home and held for ransom. His daughter scraped up tens of thousands of dollars—and paid—but her father was not freed. The family finally tracked him down 2 weeks ago. "They found him in a morgue with two gunshot wounds in his head," says Moutaz Al-Dabbas, an environmental scientist at the University of Baghdad.

In Iraq these days, science often takes a back seat to survival. But the spiral of violence didn't stop several dozen Iraqi scientists from gathering here last week for a meeting\* to showcase applied projects that can contribute to the country's reconstruction. One new initiative was unveiled: a virtual digital library of journals and other scientific materials sponsored by the U.S. State and Defense departments. And a fund of several hundred thousand dollars for peer-reviewed projects by skilled Iraqis is in the works. "Our purpose is to keep them doing science, not just sitting idle," says Abdalla Alnajjar, conference co-chair and president of the Arab Science and Technology Foundation (ASTF), a nonprofit

\* The International Conference to Engage Iraq's Science and Technology Community in Developing Its Country, 18–20 September.

organization based in Sharjah, United Arab Emirates. But to the frustration of attendees, no one stepped forward with more substantial funds for Iraqi R&D.



**Survivor.** Nahi Yousif Yaseen, director of the Iraqi Center for Cancer and Medical Genetics Research in Baghdad, heads a 72-person staff.

The corridors were filled with urgent questions, though—about how to help Iraqi researchers do science, and how to help them stay alive. At least 58 professors, 150 medical doctors, and dozens of scientists at institutes and ministries have been murdered since the Iraq war ended in April 2003, says Ahmed Moosa, an engineering professor at the Uni-

**Starting over.** Scientific labs, stripped by looters in 2003, are struggling to recover.

versity of Technology in Baghdad. Other Iraqi scientists corroborate his figures. "We feel there's a campaign to kill every scientist in Iraq," says Nahi Yousif Yaseen, director general of the Iraqi Center for Cancer and Medical Genetics Research in Baghdad. Hundreds more have been held for ransom.

Security is so poor that it prompted soul-searching at the meeting about whether grants that keep scientists in Iraq are even morally defensible. "I sometimes question the ethics of what we're doing," admits conference co-chair Arian Pregenzer, a senior scientist at Sandia National Laboratories in Albuquerque, New Mexico. Any grants for work in Iraq "are keeping scientists in a war zone," she says. "It's a terrible dilemma."

### Death trap

The first shock hit Iraqi scientists after Saddam Hussein's fall, when an orgy of looting engulfed the country. Universities and research institutions were devastated. "They took everything," says Yaseen, who founded the country's only cancer research institute in 1995. The looters made off with refrigerators, furniture, and electrical fittings. "All we had left was a damaged building," he says.

Iraq's interim government in late 2003 gave Yaseen enough money to buy second-hand equipment and pay his 72 staff members. Since then, among other accomplishments, they've established three cancer cell lines, including one from brain cancer. "The only scientific research center that's working well now in Baghdad is ours," he boasts.

But it's not clear how long the cancer center will last. One staff member was murdered last year, and in recent weeks Yaseen has received a blunt warning: several envelopes with bullets inside. "Somehow they think we're helping the American army," he says. Four bodyguards protect him and escort his three children to school and university. Yaseen, who came to Jordan for the conference, says he calls home 10 or 12 times a day to check on his family. The stress is getting to be too much. He confesses that he is now looking for a job outside Iraq: "We have to leave—or we will face death."

All Iraqi scientists must watch their backs, but some appear to be more exposed than others. Mustansiriya University, with a campus in the heart of Baghdad, has been particularly hard hit. "Many professors have been killed there," says Al-Dabbas. Earlier this month "five of my professors applied for 1-year sabbaticals," says Ali Hassan Mahawish, dean of the College of Engineering at Mustansiriya. Last May, he says, a bomb on campus killed

two students and maimed six others. Professors are growing wary of students elsewhere. At the University of Baghdad, many students have separated into Shia and Sunni cliques, says Al-Dabbas, who says it's potentially dangerous to appear to favor one group over the other. "If you give a low grade," he says, "you're frightened that they'll kill you."

#### To the rescue?

Efforts to engage Iraqi scientists in peaceful R&D began a couple of years ago. ASTF and Sandia's Cooperative Monitoring Center teamed up in August 2003 to seek out scientists, observe research facilities, and assess needs. Whereas the U.S. State Department at the time focused on weapons scientists, ASTF and Sandia embraced the whole research community. "We don't care where they used to work, what party they belong to," says Alnajjar. "We seek out scientific expertise on a merit basis." That impressed Iraqis. Until ASTF and Sandia came along, "we had no belief that anyone would come and help us. We were fed up," says Munther Naman Baker, an engineering professor at Mustansiriyah University who later was appointed director of ASTF's Baghdad office.

After their reconnaissance, ASTF and Sandia ranked research priorities, matching the U.N.'s top three: public health, water quality, and the environment. "There is a meeting of minds," says Seifeldin Abbado, officer-in-charge of the U.N. Development Group for Iraq, which funded a signature \$11 million effort to restore the southern marshlands.

Next, ASTF and Sandia invited 20 Iraqis with promising ideas to a workshop in Amman last May where they worked with international collaborators to draft proposals for funding. That was a huge culture change, says Baker. Under the old regime, he says, "we did science on order of the state." The proposals that emerged included a DNA fingerprinting unit, screening for post-traumatic stress disorder, assessing potable water supplies, and combating desertification.

Applicants presented the finished proposals at last week's meeting in Amman. It's uncertain which ones will win funding. The U.K. government is considering bankrolling the DNA forensic science project, conceived by Ali Al-Zaag, dean of the Institute of Genetic Engineering and Biotechnology at the University of Baghdad, and Hanan

Malkawi, vice dean of the Faculty of Science at Yarmouk University in Jordan. Other projects are still waiting. Some U.S. officials at the meeting spoke privately of a fund being pulled together from a variety of U.S. government agencies by the U.S. Civilian Research and Development Foundation. However, notes an official with the Arlington, Virginia-based nonprofit, "thousands of details need to be worked out."

One fully funded project was on display: the U.S. State Department's Iraqi Virtual Science Library (IVSL), a Web site



**Academic citadel.** The University of Baghdad, which suffered heavy losses after the invasion, is reportedly being divided into Sunni and Shia cliques.

(<https://ivsl.org>) with abstracts and full-text articles from thousands of journals, online course materials, and other information available free of charge to Iraqi scientists. Springer has donated access to its journals, and IVSL managers hope to acquire others at reduced rates. Sun Microsystems is donating eight servers and software, says a State Department official.

The \$340,000 initiative, managed by the U.S. National Academies, will be tested this fall at seven universities in Iraq. "The idea is to connect scientists and engineers through the literature," says George Atkinson, science adviser to the U.S. secretary of state, whose office developed the project. At the outset,

IVSL will be hosted on a Pentagon server. "We anticipate it being turned over completely to Iraq in the next few years," Atkinson says.

Fellowships will be on offer in another initiative that could allow 500 Iraqi researchers to spend up to 3 months abroad. Lab equipment and research materials, including textbooks, will be covered under the grants sponsored by Qatar, says Mohamed Djelid, director of UNESCO's Iraq office, which is managing the program. So far 48 researchers have been selected.

A job-placement initiative run by the State Department's Iraqi International Center for Science and Industry (IICSI) is making modest headway. Now in its second year, IICSI has placed 30 of 120 former weapons scientists on its rolls in jobs in Iraqi ministries. The initiative's new director, Edwin Kilbourne, a toxicologist and anthrax investigator formerly with the U.S. Centers for Disease Control and Prevention in Atlanta, Georgia, says IICSI will push harder to help former weapons scientists develop small businesses. It's a tricky proposition, he says: "They worry about whether their businesses are going to get blown up."

Managing IICSI has its challenges: Kilbourne can't visit the center, as it's located in a villa outside the so-called Green Zone that encompasses the U.S. Embassy compound. He can leave the Green Zone only with an armed escort, which would draw attention to IICSI—and make life more dangerous for scientists there.

One high-profile project involving former weapons researchers aims to learn whether the looting of the Tuwaitha Nuclear Research Center in April 2003 could pose a lingering health threat to the 100,000 people living in its vicinity. Some 200 barrels of "yellowcake"—uranium oxide—were stolen in the melee. Many were emptied and used for storing water or food, although 160 were recovered.

Last June, a team led by Iraq's Ministry of Science and Texas Tech University collected nearly 300 soil samples near Tuwaitha. They will be sent for analysis to the International Radioecology Laboratory in Slavutych, Ukraine, an outfit whose primary task is to monitor the environment around the destroyed Chernobyl nuclear reactor. (A U.S. agency is evaluating a request for funding the analysis.) Next, researchers will collect blood samples from people who may have been exposed to risky levels of radioactivity,

## Profile: Jafar Dhia Jafar

**AMMAN**—He was Saddam Hussein's chief nuclear bomb maker, but he never managed to make a bomb. Now he's living in self-imposed exile in Dubai, United Arab Emirates, working as general manager of a company that's bidding for contracts to help rebuild Iraq. Jafar Dhia Jafar still commands respect from his peers despite the fact that he was a former key adviser to Saddam Hussein. That much was evident last week when they met him at a conference here on Iraqi science. The urbane 63-year-old high-energy physicist also impresses Western experts who worry that his knowledge of nuclear weaponry may appeal to Iran or other countries suspected of pursuing nuclear arsenals. "Jafar is one of the great senior statesmen of Iraqi science," says Alex Dehgan, who ran the Coalition Provisional Authority's program for former weapons scientists.

Jafar holds strong views on the reconstruction of postwar Iraq and the plight of his colleagues there, arguing that Iraqis must take the lead in restoring the nation's infrastructure (see main text). In a wide-ranging conversation with *Science*, Jafar revealed how close Iraq was to developing a nuclear bomb and discussed the future of science in his shattered homeland.

### The making of a weaponeer

Jafar grew up in Baghdad and attended university in the United Kingdom, where in 1965 received a Ph.D. in high-energy physics from the University of Birmingham. He was a member of the team that did the first experiments on NIMROD, a 7-GeV proton synchrotron at the Rutherford High Energy Laboratory in Oxfordshire.

He returned to Iraq in 1966 to take a position at the Iraqi Atomic Energy Commission. At the time the Soviets were building a 2-MW thermal research reactor at the Tuwaitha Nuclear Research Center for medical and basic science projects. Jafar headed the physics and reactor departments there but returned to Europe in July 1970 for a stint at Imperial College London and 5 years at the European laboratory for particle physics (CERN) near Geneva. David Websdale, a physicist at Imperial College London, worked with Jafar at CERN and recalls being impressed with a prototype detector for K<sup>+</sup> mesons Jafar designed. Jafar was respected "as a talented physicist," says Websdale, who last had contact with him in the late 1970s. And Jafar was a "popular guest at bridge evenings."

including employees of the science ministry who helped corral the yellowcake barrels.

### Still waiting

Despite months of preparation, the Jordan conference organizers were unable to draw serious funding offers, leaving scientists and organizers frustrated. Some U.S. officials say they are embarrassed by how little their own government is spending on Iraqi R&D and how little of that reaches Iraqis: The lion's share of the money for the IVSL library, for example, will be spent in the United States, and nearly 50% of IICSI's budget goes to



Jafar Dhia Jafar. Starting a third career.

security. Alnajjar, who has spent months trying to wring funds from wealthy Gulf nations, says he is "disappointed with the Arab countries." He also blames international organizations for a paralysis born from waiting for a "postconflict" calm. "You can't just sit and wait for this to happen," he says.

Others such as Jafar Dhia Jafar, who led Iraq's nuclear program under Saddam Hussein and now lives in Dubai (see sidebar, above), place the blame close to home. Jafar believes that Arab countries would respond if a plea came from the Iraqi government rather than from ASTF. If the government were to ask for

A fateful invitation came in April 1975, when Saddam, then Iraq's vice president, recruited Jafar to return to Tuwaitha. Iraq had just embarked on a nuclear race with its longtime rival, Iran. In 1976, Iraq signed a \$400 million deal with France and acquired among other facilities a research and testing reactor, Osirak, that ran on highly enriched uranium (HEU) fuel. Although the French managed the fueling of Osirak under International Atomic Energy Agency (IAEA) safeguards, experts pointed out that plutonium would be produced during normal operations and could be diverted for weapons use. Jafar insists, however, that "it was still a peaceful program."

In a brief period of calm, in 1977, Jafar attended a conference on nuclear science in Iran. It was clear then, as it is today, that Iran was intent on learning how to process uranium for fuel, Jafar says: "They wanted to have a complete fuel cycle." He says he has no special insights into whether Iran aims to develop a bomb, but he believes that an Islamic country in the Middle East has as much right to have nuclear weapons as Israel does.

Jafar's path veered in a new direction as it became intertwined with that of a young nuclear chemist, Hussain al-Shahristani, who had joined Tuwaitha in 1975 to work on neutron activation analysis. "We were good friends in the office but hardly saw each other outside the labs," says Jafar. "Shahristani is a devout

Muslim, but I am not." In the turmoil that followed the 1979 revolution in Iran, Saddam, then president of Iraq, began rounding up and executing Shias.

Al-Shahristani was arrested in early December. "He was apolitical," Jafar says. "I thought for the first day or two it was all a mistake." Jafar wrote a letter to Saddam appealing for his release. There was no reply. In the meantime, he visited al-Shahristani's wife to try to reassure her; her home was being searched by security forces. Jafar became worried for his own family and decided to send his two sons to boarding school in England, where his British-born wife was receiving medical treatment.

A week or so later Jafar says he wrote another memo to Saddam about al-Shahristani, after which he was promptly arrested by the Mukhabarat intelligence service. "They probably thought I was preparing to leave the country." He was held for 20 months, although he was never tortured or even questioned, he says—unlike al-Shahristani, who Jafar later learned had been tortured from his first day of custody. With Saddam's human rights record at its most dismal in the early 1980s, Jafar says, "Shahristani is lucky that

assistance, Jafar believes that the Arab League would call a special meeting to discuss support for Iraqi scientists.

In the meantime, Pregonzer, an architect of the ASTF-Sandia initiative, says she and her colleagues are rethinking their strategy. One new emphasis, she says, will be to "get Iraqis more engaged in ongoing reconstruction efforts and other internationally funded projects in the Middle East." This could help those who are sticking it out as long as possible for the sake of the next generation, including the 3 million university students. "We don't want to leave them in the streets

he wasn't executed." Al-Shahristani escaped from prison during the Gulf War in 1991 and is now deputy speaker of Iraq's new parliament.

Jafar was released in September 1981 and returned to Tuwaitha. Iraq was already at war with Iran, and in June, Israel had bombed Osirak. Jafar insists that the nuclear program adopted military objectives "as a reaction to the bombing," to build up Iraq's defenses. He says: "Many of us were convinced that without a military-oriented program, you couldn't have a peaceful nuclear program in the Middle East."

The French refused to rebuild Osirak. Jafar set out to enrich uranium without a reactor as a clandestine bomb effort got under way. An attempt to separate isotopes using gas diffusion sputtered, and experiments on isotope separation using lasers "came to nothing," he says, as Iraq could not build or buy sufficiently high-powered, tuned lasers. Jafar was told that equipment purchases could not raise a red flag. "We had to play with these conditions. It was difficult to develop a new technology completely on our own." But his lab-scale R&D on electromagnetic isotope separation succeeded in 1985.

The next phase was a pilot plant completed in 1987, after which Iraq started building production-scale units at the Tarmiyah site. Eight out of 140 were in place by the Gulf War, when the program had grown to 8000 people. "We were producing everything indigenously." Plans called for two new production units a month, with completion expected in 1992 or 1993. The units would perform optimally if low-enriched uranium were used; 4 tons of LEU would yield more than 100 kilograms of HEU per year, enough for several warheads. Bomb design started in 1988 and was proceeding in parallel, Jafar says, with a test anticipated by 1994.

"In the meantime," he says, "things happened"—such as the Gulf War, followed by intrusive U.N. inspections. The very first inspection team visited the Al Jazeera plant near Mosul, where "yellowcake"—uranium oxide—was processed into uranium dioxide, which in turn was converted into uranium tetrachloride, the feed material for electromagnetic isotope separation. "They deduced what was going on," Jafar says. "We declared everything, more or less, in July 1991. Saddam ordered the equipment destroyed by the Republican Guards. It was impossible to carry out any kind of program after that." Jafar insists that the program was not restarted after U.N. inspectors left Iraq in 1998.

That accords with the assessment of IAEA inspectors, who after conducting 237 inspections at 148 locations in the 3 months leading up to the 2003 war stated in an April 2003 report that they "did not find in Iraq any evidence of the revival of a nuclear program"—although they noted that they did not have the time to complete their review before the war began. Jafar scoffs at prewar claims that Iraq was still pursuing the bomb—

including the discredited charge that it was trying to buy uranium ore from Niger. The United States and the United Kingdom, he claims, "had to concoct a nuclear threat."

### Picking up the pieces

After the 1991 Gulf War, Jafar was enlisted as leader of a shock brigade overseeing Iraq's reconstruction. The first task was to rebuild the oil refineries. The director of the damaged Daura refinery said that the plant could be up and running by the end of 1992. He was asked to tap resources from throughout the oil ministry and from Petrochemical Project 3, the code name for the nuclear program. "A refinery is a piping job. We had 40 teams of welders, while the Daura plant had two," Jafar says. Within 2 months Daura was on line.

The speed and efficiency of the reconstruction in 1991 offers lessons for the current situation, says Jafar, who took charge of repairing the electricity sector. Before the Gulf War, Iraq had 9776 MW of installed capacity; in the wake of the war's aerial blitz, capacity stood at 750 MW, Jafar says. Through ingenuity and the ability to call upon an army of workers—thanks in part to the omnipresent threat of imprisonment for those who didn't follow orders—the national grid was back up by June at more than half prewar capacity. Jafar's successes pleased Saddam, who made him a personal adviser from August 1992 until the fall of the regime. Although Jafar last conducted his own research in the early 1980s, he kept active in the scientific community, serving as vice president of the Iraqi Academy of Sciences.

**"Without a military-oriented program, you couldn't have a peaceful nuclear program in the Middle East."**

—JAFAR DHIA JAFAR

Jafar fled Baghdad on 7 April 2003 during the Coalition invasion, crossing into Syria and going to Dubai. There, Jafar says he submitted to questioning by U.S. and U.K. intelligence agents. "My objective was to show them that they committed a grave mistake by invading Iraq under false pretenses," he says.

He later co-founded Uruk Engineering Services, a Dubai firm that competes for reconstruction contracts in Iraq. Uruk has completed work on the refurbishment of a power station and is competing for a contract to develop the Zubair gas field in southern Iraq.

Although Jafar's current work is peaceful, nonproliferation experts say it's paramount that U.S. officials keep him on their radar screen. "The U.S. has a tremendous opportunity to obtain his input and benefit from his prestige," says Dehgan. "Perhaps even more compelling, the dangers of not engaging him may hold severe penalties for our regional security."

—R.S.

to be enticed by terrorists," says Moosa.

Some, however, may be better off getting out of the country. Moving scientists to a safe haven could give them "a chance to rejuvenate," Pregoner says. "The goal is that they come back." One possibility, she says, is the new Middle East Consortium on Infectious Disease Surveillance. The public health and early-warning network could easily place a few

**Lingering risk.** Researchers aim to study exposure to drums from the Tuwaitha nuclear center.

Iraqis in Jordan or Egypt, Pregoner says: "These sorts of things

don't cost a lot of money." Jafar, speaking from personal experience, worries that such a strategy could backfire in the long run: "If scientists go out of the country, once they settle down it will be difficult to uproot them and send them back."

Iraqi scientists say it's a heart-wrenching decision to forsake their homeland. Baker, for one, is planning to leave Baghdad in the coming weeks to take a university position in Jordan. If it were his decision alone, he says, he might stay. But concerns for his family's safety trump patriotism. "Every day," he says, "is worse than the last." —RICHARD STONE



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