Comprehensive Report

of the Special Advisor to the DCI on
Iraq's WMD
With Addendums

30 September 2004

volume II of III

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Delivery Systems

Still, I believe that the Arab nation has a right to ask: thirty nine missiles? Who will fire the Fortieth?

Saddam Husayn

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Key Findings

Since the early 1970s, Iraq has consistently sought to acquire an effective long-range weapons delivery capability, and by 1991 Baghdad had purchased the missiles and infrastructure that would form the basis for nearly all of its future missile system developments. The Soviet Union was a key supplier of missile hardware and provided 819 Scud-B missiles and ground support equipment.

Iraq's experiences with long-range delivery systems in the Iran/Iraq war were a vital lesson to Iraqi President Saddam Husayn. The successful Iraqi response to the Iranian long-range bombardment of Baghdad, leading to the War of the Cities, probably saved Saddam.

By 1991, Iraq had successfully demonstrated its ability to modify some of its delivery systems to increase their range and to develop WMD dissemination options, with the Al Husayn being a first step in this direction. The next few years of learning and experiments confirmed that the Regime's goal was for an effective long-range WMD delivery capability and demonstrated the resourcefulness of Iraq's scientists and technicians.

Iraq failed in its efforts to acquire longer-range delivery systems to replace inventory exhausted in the Iran/Iraq war. This was a forcing function that drove Iraq to develop indigenous delivery system production capabilities.

Desert Storm and subsequent UN resolutions and inspections brought many of Iraq's delivery system programs to a halt. While much of Iraq's long-range missile inventory and production infrastructure was eliminated, Iraq until late 1991 kept some items hidden to assist future reconstitution of the force. This decision and Iraq's intransigence during years of inspection left many UN questions unresolved.

- Coalition airstrikes effectively targeted much of Iraq's delivery systems infrastructure, and UN inspections dramatically impeded further developments of long-range ballistic missiles.

- ***It appears to have taken time, but Iraq eventually realized that sanctions were not going to end quickly.*** This forced Iraq to sacrifice its long-range delivery force in an attempt to bring about a quick end to the sanctions.

- After the flight of Husayn Kamil in 1995, Iraq admitted that it had hidden Scud-variant missiles and components to aid future reconstitution but asserted that these items had been unilaterally destroyed by late 1991. The UN could not verify these claims and thereafter became more wary of Iraq's admissions and instituted a Regime of more intrusive inspections.

- ***The Iraq Survey Group (ISG) has uncovered no evidence Iraq retained Scud-variant missiles, and debriefings of Iraqi officials in addition to some documentation suggest that Iraq did not retain such missiles after 1991.***

While other WMD programs were strictly prohibited, the UN permitted Iraq to develop and possess delivery systems provided their range did not exceed 150 km. This freedom allowed Iraq to keep its scientists and technicians employed and to keep its infrastructure and manufacturing base largely intact by pursuing programs nominally in compliance with the UN limitations. ***This positioned Iraq for a potential breakout capability.***

- Between 1991 and 1998, Iraq had declared development programs underway for liquid- and solid-propellant ballistic missiles and unmanned aerial vehicles (UAVs).

Iraq's decisions in 1996 to accept the Oil-For-Food program (OFF) and later in 1998 to cease cooperation with UNSCOM and IAEA spurred a period of increased activity in delivery systems development. The

pace of ongoing missile programs accelerated, and the Regime authorized its scientists to design missiles with ranges in excess of 150 km that, if developed, would have been clear violations of UNSCR 687.

- By 2002, Iraq had provided the liquid-propellant Al Samud II—a program started in 2001—and the solid-propellant Al Fat'h to the military and was pursuing a series of new small UAV systems.

- ***ISG uncovered Iraqi plans or designs for three long-range ballistic missiles with ranges from 400 to 1,000 km and for a 1,000-km-range cruise missile, although none of these systems progressed to production and only one reportedly passed the design phase. ISG assesses that these plans demonstrate Saddam's continuing desire—up to the beginning of Operation Iraqi Freedom (OIF)—for a long-range delivery capability.***

Procurements supporting delivery system programs expanded after the 1998 departure of the UN inspectors. Iraq also hired outside expertise to assist its development programs.

- ISG uncovered evidence that technicians and engineers from Russia reviewed the designs and assisted development of the Al Samud II during its rapid evolution. ISG also found that Iraq had entered into negotiations with North Korean and Russian entities for more capable missile systems.

- According to contract information exploited by ISG, Iraq imported at least 380 SA-2/Volga liquid-propellant engines from Poland and possibly Russia or Belarus. While Iraq claims these engines were for the Al Samud II program, the numbers involved appear in excess of immediate requirements, suggesting they could have supported the longer range missiles using clusters of SA-2 engines. Iraq also imported missile guidance and control systems from entities in countries like Belarus, Russia and Federal Republic of Yugoslavia (FRY). (Note: FRY is currently known as Serbia and Montenegro but is referred to as FRY in this section.)

In late 2002 Iraq was under increasing pressure from the international community to allow UN inspectors to return. Iraq in November accepted UNSCR 1441 and invited inspectors back into the country. In December Iraq presented to the UN its Currently Accurate, Full, and Complete Declaration (CAFCD) in response to UNSCR 1441.

- While the CAFCD was judged to be incomplete and a rehash of old information, it did provide details on the Al Samud II, Al Fat'h, new missile-related facilities, and new small UAV designs.

- In February 2003 the UN convened an expert panel to discuss the Al Samud II and Al Fat'h programs, which resulted in the UN's decision to prohibit the Al Samud II and order its destruction. Missile destruction began in early March but was incomplete when the inspectors were withdrawn later that month.

The CAFCD and United Nations Monitoring, Verification, and Inspection Commission (UNMOVIC) inspections provided a brief glimpse into what Iraq had accomplished in four years without an international presence on the ground.

Given Iraq's investments in technology and infrastructure improvements, an effective procurement network, skilled scientists, and designs already on the books for longer range missiles, ISG assesses that Saddam clearly intended to reconstitute long-range delivery systems and that the systems potentially were for WMD.

- Iraq built a new and larger liquid-rocket engine test stand capable, with some modification, of supporting engines or engine clusters larger than the single SA-2 engine used in the Al Samud II.

- Iraq built or refurbished solid-propellant facilities and equipment, including a large propellant mixer, an aging oven, and a casting pit that could support large diameter motors.

- Iraq's investing in studies into new propellants and manufacturing technologies demonstrated its desire for more capable or effective delivery systems.

Evolution of Iraq's Delivery Systems

Throughout its recent history, Iraq has consistently sought to maintain an effective long-range weapons delivery capability, beginning with its acquisition of Scud missiles in the 1970s and 80s and subsequent modifications to increase their range. After expelling the UN inspectors in 1998, the Regime authorized the development of longer-range delivery systems, demonstrating its commitment to acquiring these potential WMD delivery platforms.

- After Desert Storm, the international community learned that Iraq had developed CW and BW warheads for Al Husayn missiles, was pursuing a nuclear weapon for delivery by ballistic missile, and had pursued development of a UAV for CW/BW delivery. WMD delivery was a central role for Iraq's missile and UAV systems.

- During the UNSCOM inspection years (1991-1998), Iraq embarked on a number of delivery system programs that helped retain the expertise and infrastructure needed to reconstitute a long-range strike capability, although ISG has no indication that was the intent.

- ***After OIF, ISG found evidence for several new long-range delivery system designs, but has not found evidence for new WMD payloads for these, or any, delivery systems***.

The Regime Strategy and WMD Timeline
For an overview of Iraqi WMD programs and policy choices, readers should consult the Regime Strategy and WMD Timeline chart, enclosed as a separate foldout and in tabular at the back of Volume I. Covering the period from 1980-2003, the timeline shows specific events bearing on the Regime's efforts in the BW, CW, delivery systems and nuclear realms and their chronological relationship with political and military developments that had direct bearing on the Regime's policy choices. (These events are also provided in tabular form in the Annex section).

Readers should also be aware that, at the conclusion of each chapter, ISG has included foldout summary charts that relate inflection points— critical turning points in the Regime's WMD policymaking—to particular events, initiatives, or decisions the Regime took with respect to specific WMD programs. Inflection points are marked in the margins of the text with a red triangle.

Ambition (1980-91)
In the early 1970s, Iraq embarked on a determined path to acquire a robust delivery system capability, and by 1991 Iraq had purchased the missiles and infrastructure that would form the basis for nearly all of its future missile system developments. The Soviet Union was a key supplier of missile systems in Iraq's bid to establish a liquid-propellant ballistic missile force. Other countries played significant roles in the establishment of related infrastructure. The Iran-Iraq War was a key spur to these missile system developments. In particular, Iraq needed to achieve longer range missiles. Iran could strike Iraqi cities with Scuds, but Iraq could not strike Tehran with similar-range systems.

- After signing contracts with the Soviet Union in 1972, Iraq between 1974 and 1988 received 819 Scud-B missiles; 11 MAZ-543 transporter-erector-launchers; and other ground support equipment, propellants, and warheads.

- In 1980 Iraq and Yugoslavia agreed to develop and produce a small battlefield artillery rocket called the Ababil-50 in Iraq and the Orkan M-87 in Yugoslavia. The Ababil-50 inspired an interest in solid-propellant missiles.

- In 1984, Iraq, Egypt, and Argentina signed an agreement (amended in 1985 and 1987) to produce the BADR-2000—a solid-propellant boosted two-stage ballistic missile with range capabilities up to 750 km. By 1989 deliveries fell so far behind schedule that the agreement, was canceled. However, before Iraq terminated the agreement it received missile designs, two large solid-propellant mixers, and other infrastructure.

- In 1987, unable to attack Tehran directly ***during the Iran-Iraq war*** using standard Scud-B missiles, Iraq performed a simple modification to produce the Al Husayn with a 650-km range and reduced payload

mass. At first, producing one Al Husayn missile required three Scud airframes, but this rapidly evolved to a one-for-one ratio allowing recovery of previously consumed missiles.

In 1987, Iraq successfully demonstrated its ability to both modify some of its delivery systems to increase their range and to develop crude WMD dissemination options by 1990, with the Al Husayn being a first step in this direction.

- After successfully undertaking the Al Husayn modification project, Iraq initiated another Scud modification project known as Al 'Abbas to increase the range to 950 km. The Al 'Abbas reached a range of about 850 km during a flight test in 1988, but the program experienced numerous problems and was not flown after 1990.

- In 1989, Iraq began researching the Al 'Abid 3-stage space launch vehicle (SLV), consisting of five Scud-type missiles strapped together to form the first stage (a concept using a solid rocket fourth stage never moved beyond the design phase). The Al 'Abid was tested on 5 December 1989 and successfully lifted off the launch pad; however, an inter-stage collapse caused the SLV to fail and there were no further flight tests. The Al 'Abid program continued until late 1990.

- ***Iraq invaded Kuwait in August 1990*** and, in the ensuing Desert Storm, used Al Husayn and Al Hijarah missiles against targets in Israel and Saudi Arabia.

- In 1990, Iraq successfully designed and tested crude "special" CW or BW agent-filled warheads for the Al Husayn missile. Serial production occurred between August and September 1990 producing a stockpile of CBW warheads.

- Also in this time frame, Iraq initiated two projects—known as Fahad-300 and Fahad-500—to convert an SA-2 surface-to-air missile (SAM) into a surface-to-surface missile (SSM) with design ranges of 300 km and 500 km, respectively. The Fahad- program was canceled in July 1989 but other similar projects such as Al Rohma (Javelin) SAM continued. Iraq was actually flight-testing one such undeclared program, the G-1, while UNSCOM was undertaking inspections in 1993. ISG discovered other SA-2 conversion projects from the late 1990s up to OIF that probably trace their origins to the Fahad programs.

- By January 1991, Iraq had converted a MiG-21 into a remotely piloted vehicle (RPV) and had tested BW simulant dissemination from modified Mirage F-1 drop tanks. The MiG-21 conversion program was canceled in 1991, but these initial steps most likely laid the groundwork for future RPV developments.

Decline (1991-96)

Desert Storm and subsequent UN resolutions and inspections brought many of Iraq's delivery system programs to a halt. While much of Iraq's missile inventory and production infrastructure was eliminated, Iraq kept some Scud variant missiles hidden to assist future reconstitution of the force until the end of 1991. This decision, coupled with the unilateral destruction of WMD, and Iraq's intransigence during the inspection years left many questions unresolved for the UN. ***Baghdad's prime objective was to rid Iraq of sanctions, which would enable Iraq to develop its delivery system programs at a quicker pace and to make their systems more accurate. Iraq's fear of Iran's growing military strength and Baghdad's concern that inspections would expose its weaknesses to Iran led Baghdad to obfuscate the inspection process.***

- United Nations Security Council Resolution (UNSCR) 687 prohibited Iraq from developing or possessing any ballistic missiles with a range in excess of 150 km—a restriction reinforced by subsequent resolutions—and established an organization called the United Nations Special Commission (UNSCOM) with the mandate to police these restrictions. In the summer of 1991, UNSCOM oversaw the destruction of 48 Al Husayn missiles, 50 warheads, 6 MAZ-543 launchers and 2 Al Nida' launchers.

- After ***the flight of Husayn Kamil***, Saddam's son-in-law and head of the weapons programs of the Military Industrialization Commission (MIC),

Iraq in 1995 admitted that it had intentionally concealed two Scud-type missiles and associated equipment from the UN until late 1991 to prevent their destruction so that they could be used in the future to reconstitute the force. The Iraqi government declared it unilaterally destroyed these items, but the UN could not completely verify those claims and became much more wary of Iraq's admissions and instituted a regime of more intrusive inspections.

- Husayn Kamil was the key to the delivery system development process being closely involved in the appointments of key personnel and even run-of-the-mill design reviews. His flight from Iraq effectively ended all work on long-range missiles until 1998.

- Documentary evidence reveals that Iraq received all of its Scud missiles deliveries from the Soviet Union. The documents also account for the disposition of Iraq's Scud force. ***This information, apparently never provided to the UN, suggests Iraq did not have Scud-variant missiles after 1991, resolving a key question for the international community***.

- In the area of solid-propellants, UNSCOM supervised the "destruction" of two remaining 300-gallon mixer bowls and a solid-propellant mixer meant for the BADR-2000 program. UNSCOM also supervised the "destruction" of other equipment associated with the BADR-2000 first stage motor production and declared the BADR-2000 motor case aging oven "destroyed." In effect, this equipment was merely disabled and much of it would resurface in the program later once Iraq was no longer under a monitoring and verification regime.

UNSCR 687 prohibited chemical, biological, and nuclear weapons programs but permitted the development and possession of ballistic missiles with up to a 150 km range. Iraq kept its scientists and technicians employed and its missile infrastructure and manufacturing base largely intact by pursuing programs nominally in compliance with the UN limitations. This positioned Iraq with a breakout capability. During the mid-to-late 1990s, Iraq expanded and modernized its missile-production infrastructure and had development programs for liquid- and solid-propellant ballistic missiles and UAVs.

- ***Even at a time of diminishing resources and as the economy moved to its late 1995 low point, Iraq supported its missile programs as a matter of priority. This priority ensured that support was sustained up to OIF.***

- Iraq's initial foray into liquid-propellant ballistic missiles after Desert Storm started with the Ababil-100 program (later replaced by the Al Samud) in 1993. This missile program relied on SA-2 technology and Iraq's familiarity with Scud manufacturing and was monitored closely by the UN. Research and development continued until 2001 when the program was terminated and replaced by the Al Samud II.

- Research for a solid-propellant ballistic missile under the Ababil-100 program (later renamed Al Fat'h) began before Desert Storm. This program was based in part on the Ababil-50, with an initial goal of achieving a range of 100 km. Research and development on this program continued through 2002.

- In 1995, after the MiG-21 conversion failure in 1991, the Iraqis resumed efforts to convert a manned aircraft into a RPV, this time with L-29 trainer aircraft. Research continued intermittently until 2001 when the program was terminated. 'Abd-al-Tawab 'Abdallah Al Mullah Huwaysh, the former Minister of Military Industrialization, stated that the L-29 had the same mission as the MiG-21. ***ISG judges that the purpose of the MiG-21 RPV program was to deliver CW/BW***.

Recovery (1996-98)

Iraq's decisions in 1996 to accept OFF and later in 1998 to cease cooperation with UNSCOM and IAEA spurred a period of increased activity in delivery systems development. The pace of ongoing missile programs accelerated, and the Saddam Regime authorized the design of long-range missiles that were clear violations of UNSCR 687.

Iraq's ballistic missile programs experienced rapid advancement compared to the previous five years of stunted development and concerned new ideas for longer range missiles, some based on old concepts. Given the ever-decreasing effectiveness of sanctions, Iraq was able to consider bolder steps in areas where it still had technical difficulties. If the sanctions regime remained strictly enforced, there would have been little or no effort by Iraq to address these shortfalls.

- ISG discovered that Iraq in 1997 restarted efforts to convert SA-2 SAMs into ballistic missiles, which contravened an UNSCOM letter restricting this kind of work. This project was canceled in 1998 but probably restarted in 2000 with the Sa'd project to create a 250-km-range missile. Research for the Sa'd project continued up to the time UN inspectors returned in 2002.

- According to a former engineer within the Iraqi missile program, in 1997 or 1998 during a monthly Ballistic Missile Committee meeting, Huwaysh openly stated he wanted a missile with a range of 1,000 km.

- According to Kamal Mustafa 'Abdallah Sultan Al Nasiri, a former Secretary General of the Republican Guard (SRG), in the summer of 1999, Huwaysh, in a speech to SRG and Republican Guard members, promised that the range of an unspecified missile system would be extended to 500 km, though this would take five years to accomplish.

- Iraq began flight-testing the Al Fat'h in 2000 and continued through 2002, but Iraq was not able to acquire or develop a suitable guidance system. Iraq began deploying unguided Al Fat'h missiles to the army in late 2001.

- In 1999-2000 the Iraqis began developing the Al 'Ubur SAM system, which would use a modified, longer Al Fat'h rocket motor. Iraq considered, but did not pursue, using the Al 'Ubur motor in a single-stage ballistic missile that could have exceeded 200 km in range.

- After 2000-2001, Iraq began an effort to extend the shelf life of FROG-7 (LUNA) and Ababil-50 rockets by replacing their aging double-base solid rocket motors with composite solid-propellant, which also improved the performance of these rockets. Renamed Al Ra'd and Al Nida', respectively, these efforts helped advance the composite solid-propellant manufacturing infrastructure in Iraq.

- ***Around 2000, Saddam ordered the development of longer range missiles. In response, Huwaysh asked his missile scientists to see what was feasible.*** Drawings dated August 2000 show two missiles using a cluster of either two or five SA-2 engines. These designs could have resulted in missiles with maximum ranges of about 500 and 1,000 km, but the designs did not move forward because the program lacked written authorization from Saddam.

- ***Following Huwaysh's orders, Iraq pursued efforts to develop a long-range (400-1,000 km) solid-propellant ballistic missile***. Source accounts give various dates for this event, but it was most likely spring 2000. Initial concepts included using a cluster of Al Fat'h motors or developing a larger diameter motor. Iraq also pursued a motor with a diameter of 0.8 or one meter for use in a single-stage missile. Iraq attempted to use a barrel section from the pre-1991 Supergun project to create a prototype one-meter-diameter solid rocket motor, but the effort failed because of material incompatibilities when Iraqi technicians tried to weld the Supergun section to the motor end-dome.

- In 2001 the Al Samud II replaced the Al Samud program because of instability problems. Flight tests began in August 2001, and the Al Samud II was deployed to the Army in December 2001.

Iraq after 1998 continued with its HY-2 modification efforts with the HY-2 range extension project and started a completely new effort to increase the range of the HY-2 cruise missile to 1,000 km.

- The first effort was a straightforward project that replaced the existing rocket propulsion system with one that used a higher energy fuel. This change

allowed an increase in range to greater than 150 km. According to one Iraqi scientist, the first successful flight test of the extended-range HY-2 occurred in August 1999. Huwaysh commented that a extended-range HY-2 may have been fired during OIF, targeting Kuwait.

- The second effort began in late 2001 when the Office of the President suggested to MIC that it develop a 1,000-km-range cruise missile. This project, later named Jinin, would attempt to replace the HY-2's liquid-propellant rocket engine with a modified helicopter turboshaft engine to extend its range to 1,000 km. Work began in 2002, and Iraq had conducted some engine-related tests by the time UN inspectors returned. At that time, one official working on the project judged it was three to five years from completion.

Concurrent with the failures of the L-29 RPV program, Iraq began in 2000 to pursue new, long-range UAV options.

- Iraq remained interested in UAVs, and the MIC ordered the development of indigenous reconnaissance UAVs and target drones. Iraq's Ibn-Firnas group after 1998 developed the Al Musayara-20 UAV as a battlefield reconnaissance UAV.

- Iraq began a second, more secret, indigenous UAV development program in early 2000, called Al Quds, which would focus on meeting military requirements for airborne electronic warfare programs. However the Al Quds UAVs were still in development at the start of OIF.

Delivery system-related procurement expanded in late 1998 after the departure of the UN inspectors. Iraq also hired outside expertise to assist its development programs. Money was pouring into Iraq's delivery system programs, and Iraqi front companies took advantage of the freedom to operate without UN oversight.

- Iraq hired technicians and engineers from Russian companies to review the designs and assist development of the Al Samud II, perhaps contributing to its rapid evolution.

- Iraq entered into negotiations with North Korean and Russian entities for more capable missile systems. Iraq and North Korea in 2000 discussed a 1,300-km-range missile, probably the No Dong, and in 2002 Iraq approached Russian entities about acquiring the Iskander-E short-range ballistic missile (SRBM).

- According to contract information, Iraq imported at least 380 SA-2/Volga liquid-propellant engines from Poland and possibly Russia or Belarus. Iraq claims these engines were for the Al Samud II program, but the numbers involved appear far in excess of immediate requirements, suggesting they could have supported the longer range missiles using clusters of SA-2 engines. Iraq also imported missile guidance and control systems from entities in Belarus, Russia and Federal Republic of Yugoslavia (FRY).

Miscalculation (2002-2003)

The next move of the Regime commenced with Saddam's ill-conceived reaction to the terrorist attacks of 9/11, allowing him to be aligned with the "Axis of Evil." In late 2002, Iraq was under increasing pressure from the international community to allow UN inspectors to return. Iraq in November accepted UNSCR 1441 and invited UN inspectors back into the country. That December, Iraq presented to the UN its Currently Accurate, Full, and Complete Declaration (CAFCD). The CAFCD was largely a repeat of old information, but it did provide details on the Al Samud II, Al Fat'h, and new missile-related facilities.

- After Iraq disclosed in its CAFCD that, on at least 13 occasions, its Al Samud II missile had reached ranges beyond 150 km, the UN put a stop to Al Samud II flight-testing until they could further assess the system's capabilities. UNMOVIC convened a panel of missile experts in February 2003, which concluded that the Al Samud II violated UN statutes, and, therefore, the program should be frozen and the missiles destroyed. Beginning in March, UNMOVIC supervised the destruction of 72 missiles and the disablement of 3 launchers. The missile destruction program was incomplete when the inspectors left in mid-March, leaving Iraq with

Al Samud II missiles that could be used against Coalition forces. Iraq launched approximately five Al Samud II missiles against Coalition forces during OIF before the system was recalled due to failures.

- The Al Karamah State Establishment, later known as Al Karamah General Company, detailed design work for long-range missiles using SA-2 engine clusters through 2002. Huwaysh claimed that he ordered one copy of these designs be given to him and that all other evidence of the program destroyed to avoid detection by UNMOVIC inspectors.

- The Sa'd SA-2 conversion project, researched by Al Kindi State Establishment, was abandoned prior to the arrival of UN inspectors. ***ISG learned, however, that another group embarked on a crash program to convert SA-2s to SSMs after UNMOVIC inspectors departed. Two SA-2s were converted but never fired***.

- Iraq declared that its Al Fat'h missile had exceeded 150 km during flight tests to the UN. As with the Al Samud II missile, the UN ordered that Iraq cease all flight tests of the system until they could further evaluate the system's capabilities. By the start of OIF, a guided version of the Al Fat'h was within weeks of flight-testing. Even without a guidance system, the Al Fat'h proved itself to be a viable weapon system, and the Iraqi Army fired between 12 and 16 missiles during OIF.

- Iraq's small UAV programs had demonstrated some success, including an autonomous 500-km flight, and given time most likely would have produced larger UAVs with greater payload capabilities. The evidence uncovered by ISG suggests that the UAV programs active at the onset of OIF were intended for reconnaissance or electronic warfare.

The CAFCD and UNMOVIC inspections provided a brief glimpse into what Iraq had accomplished in four years without an international presence on the ground. Given Iraq's investments in technology and infrastructure improvements, an effective procurement network, skilled scientists, and designs already on the books for longer range missiles, ISG assesses that, absent UN oversight, Saddam clearly intended to reconstitute long-range delivery systems, potentially for WMD.

- Iraq constructed a new liquid-rocket engine test stand that was larger and more capable than the existing engine test stand. The new stand, with modifications, would have been able to support tests of more powerful engines or clusters of engines. Although ISG found no evidence that tests of more powerful engines had occurred, Iraq had clearly begun to establish the infrastructure to support such tests in the future.

- Iraq undertook efforts to improve its composite solid-propellant infrastructure. Iraq repaired one of the two 300-gallon mixers and two bowls from the BADR-2000 program and tried to repair the second mixer, although reports vary as to the success. According to two former Iraqi officials, the mixer was used for a short time in 2002 and then dismantled before UN inspectors returned. In addition, Iraq built an annealing chamber capable of handling rocket motor cases with diameters greater than one meter. Other infrastructure improvements included new, larger diameter casting chambers and a significant increase in propellant component production capabilities.

- Iraq studied new propellants and manufacturing technologies demonstrating its desire for more capable or effective delivery systems. For example, a liquid-propellant rocket engine test on 18 March 2001 used AZ-11 fuel instead of the usual TG-02, in an effort to enhance the engine's performance. ISG learned that a Liquid Fuels Committee was established in August 2000 to research the performance capabilities for various propellants and techniques for producing candidate propellants or precursors, some advanced up to pilot scale.

Resolving the Retained Scud-Variant Missile Question

ISG acquired information suggesting that after 1991 Iraq did not possess Scud or Scud-variant missiles. Interviews with several former high-level Iraqi officials, visits to locations where missiles were reportedly hidden, and documents reportedly never disclosed to the UN, all appear to confirm that Iraq expended or destroyed all of the 819 Scud missiles it acquired from the Soviet Union.

- A recently exploited document contains information on all of the 819 Scud missiles imported from the Soviet Union with a break down by serial number of their disposition. This document—reportedly never shared with the UN, although the contents had been discussed with UN officials—provides an Iraqi analysis for the discrepancies in the accounting for its Scud missiles to the UN. A partial translation of the document can be found in the Delivery Systems Annex.

- Husam Muhammad Amin Al Yasin, the former director of the National Monitoring Directorate (NMD), admitted to knowing about the retention of two missiles for reverse-engineering but said the missiles were destroyed in 1991.

- According to Hazim ‘Abd-al-Razzaq Ayyubi Al Shihab, the former commander of the Surface-to-Surface Missile (SSM) Forces, the only retained Scud-variant missiles were destroyed in 1991. Two missiles that were to be used for reverse engineering were unilaterally destroyed by December 1991. Hazim claimed that no other Scud missiles or equipment were retained.

A few former high-level Regime officials have provided conflicting information regarding the retention of Scud-variant missiles. Further questioning has not resolved these conflicts. Additionally, ISG has investigated several reports from sources of unknown credibility concerning the locations of Scud missiles, but we have not found evidence at those locations to support these claims.

- ‘Abd-al-Tawab ‘Abdallah Al Mullah Huwaysh, the head of MIC and Deputy Prime Minister, stated that he had been convinced that Iraq had retained two to four Scud-variant missiles as a result of a 2002 conversation with Qusay Saddam Husayn. Huwaysh described Qusay’s irritation with ‘Amir Muhammad Rashid Al ‘Ubaydi, the former Minister of Oil then charged with resolving the Scud material balance, who had pestered Qusay over the difference in Scud materiel balance between UNMOVIC and Iraq. Huwaysh then commented that he knew nothing about the location of the missiles or their status and that his opinion was based on Qusay’s reaction. However, Huwaysh speculated that a highly restricted area near the so-called “Khanaqin triangle” would have been an ideal location to hide these missiles, since the Special Republican Guard (SRG) controlled the area. Huwaysh was unable to provide any confirmatory evidence to his claim.

ISG believes that the balance of credible reporting and documentary evidence suggests that, after 1991, Iraq no longer possessed Scud-variant missiles. Though some former high-level officials offer speculation and suspicions that Iraq has retained Scud-variant missiles, exhaustive investigation by ISG has not yielded evidence supporting these claims.

Liquid-Propellant Missile Developments

Iraq demonstrated its ability to quickly develop and deploy liquid-propellant ballistic missiles, such as the Al Samud II, against UN guidelines. ISG believes that, given the order to proceed, Iraq had the capability, motivation and resources to rapidly move ahead with newer longer range ballistic missile designs.

Iraq began its indigenous liquid-propellant ballistic missile efforts in the early 1990s with the Ababil-100—later known as the Al Samud. These efforts lead to the more successful Al Samud II program, officially beginning in 2001. Through a series of debriefings of high-level officials from Iraq’s missile programs, together with document exploitation, ISG has been able to build a better understanding of the Al Samud II program. ***Although the infrastructure and technical expertise were available, there is no evidence suggesting Iraq intended to design CBW warheads for either the Al Samud or the Al Samud II system***.

Early Liquid-Propellant Missile Efforts

As early as 1988, Iraq displayed ambitions to develop an indigenous, liquid-propellant ballistic missile. These early developmental efforts included the unsuccessful Fahad-300/500 and the G-1 projects. In 1992, an indigenous SA-2 replication (the Al Rafadiyan project) also failed but was tied with the Ababil-100 project. The Ababil project—initially intended as a compliance measure addressing the UN sanctions of 1991; limiting the range to 150 km and later renamed the Al Samud —began as a 500-mm-diameter missile designed by Dr. Hamid Khalil Al 'Azzawi and Gen Ra'ad Isma'il Jamil Al Adhami at Ibn-al Haytham. The program experienced various problems, especially with the missile's stability. In 1993, Dr. Muzhir [Modher] Sadiq Saba' Khamis Al Tamimi, then Director of both Al Karamah and Ibn-al Haytham, proposed a missile design, which was deemed more stable due to its having an increased diameter of 750 mm. After reviewing various designs of the Ababil project, UNSCOM restricted missile programs to having a diameter of no more than 600 mm in 1994. Husayn Kamil held a competitive design review between Dr. Muzhir's new 600-mm-diameter design and Gen Ra'ad's 500-mm design; Gen Ra'ad's design succeeded. After several years of limited success at MIC, Gen Ra'ad was removed as the head of the program, and Dr. Muzhir was put in charge of the Al Samud program in 1999. Muzhir experimented with the design of the missile—increasing its reliability—but work on this program ceased in 2000. All efforts were then refocused on the Al Samud II project. See the Delivery Systems Annex for further information on Dr. Muzhir and Gen Ra'ad.

Diameter Restriction

On 17 March 1994, Rolf Ekeus, the Executive Chairman of UNSCOM, submitted a letter to 'Amir Muhammad Rashid Al 'Ubaydi concerning designs for the Ababil-100 liquid engine missile.

". . . Iraq disclosed a new design for the Ababil-100 liquid engine missile still under research and development. . . this new design provided for a substantial increase of an airframe's diameter, from 500 mm to 750 mm. Our analysis concluded that such a large diameter is not appropriate or justified for missiles with ranges less than 150 km. . . the Commission has to state that any increase of the diameter in the current design of the Ababil-100 liquid engine missile exceeding 600 mm is not permitted."

Al Samud II

Iraq researched and developed the Al Samud II missile despite UN provisions, which prohibited such a system with its specification. Not only did the missile have range capabilities beyond the 150-km UN limit, but also Iraq procured prohibited items as well as received foreign technical assistance to develop and produce this system. ***ISG, which has developed a comprehensive history of the system, has no evidence indicating that Iraq was designing CBW warheads for the missile.***

Huwaysh's official approval for the Al Samud II diameter increase to 760 mm occurred in June 2001, despite the 1994 letter from UNSCOM Executive Chairman Rolf Ekeus specifying that UNSCOM restricted the diameter of Iraq's Ababil-100 missile to less than 600 mm. According to officials within Iraq's missile program, the 760-mm-diameter design was chosen because this gave the missile more stability than the unsuccessful smaller diameter missile and this dimension also allowed Iraq to use HY-2 components for the missiles.

- According to a former Iraqi missile program official, Huwaysh approved the 760-mm-diameter design for the Al Samud II in June 2001. Engineers within the program strongly believed that the 500-mm diameter Al Samud was going to be unsuccessful from

the very beginning. They had determined, based on their experience and knowledge of Soviet ballistic missile systems, the length/diameter (L/D) ratio of such missiles should be between 8 and 14 but that 12.5 was the optimum. See Figure 1 for a diagram of the Al Samud II missile and Figure 2 for a photo of the Al Samud II missile.

—***ISG believes that discussions of an "optimum" L/D are fallacious. Iraqi insistence that the diameter increase was intended solely to meet a specific L/D is more probably a ruse to increase the missile's internal volume—ostensibly for increasing the fuel capacity—thereby further increasing the maximum range potential.***

—Although the L/D of the 760-mm-diameter design may be an improvement over that of the 500-mm-diameter designs, this is only one of many inter-dependant parameters contributing to the missile's stability.

- An Al Karamah official claimed that Dr. Muzhir, who had previously developed a 750-mm design by 1993, discovered that the airframe and ring assembly for the HY-2 cruise missile was based on a 760-mm diameter. Because of time constraints, these items could easily be used to quickly develop and manufacture his 760-mm-diameter missile. Figure 3 depicts an early Al Samud II using an HY-2 airframe.

- Huwaysh stated that the larger diameter design allowed an additional fuel tank. ***ISG has not found evidence that Iraq intended to add an additional fuel tank to the Al Samud II.***

The capability of the Al Samud II missile quickly showed a marked improvement over the unsuccessful Al Samud program. After several flight tests, the first of which occurred in August 2001, Iraq began a production ramp-up of the missile in September 2001. Several sources have corroborated Iraq's efforts to improve the accuracy of the system, using components, expertise, and infrastructure from other missile programs to accelerate fielding the Al Samud II. The key parameters for the Al Samud II are listed in Table 1.

Table 1
Key Parameters of Al Samud II

Key Parameters	
Propellants	Fuel (TG-02) Oxidizer (AK20K)
Engine	Modified SA-2 Engine (Volga)
Guidance and Control	C601 and C611 gyroscopes
Body	Aluminum Alloy with Stainless Steel Rings

- A senior official within Iraq's missile program stated that the Al Samud II used gyroscopes taken from the guidance system of C601 and C611 cruise missiles.

- Up to November 2002, a timer system was used by Al Karamah to provide a simple determination of the time for engine cut-off, regardless of the velocity achieved. After that date, the timer was replaced by an integrating axial accelerometer in the analog control system, which was designed to provide an accurate determination of the engine cut-off velocity. This consisted of an AK-5 accelerometer integrated into the control system, calculating the missile velocity using digital integration of the axial acceleration. This modified control system would issue the engine shut down command signal when the target velocity had been reached. A range count, similar to that of the Scud and Al Husayn missiles, could be entered from the launcher to preset the missile range using prelaunch data.

- Al Karamah also began the design of a completely digital compensator to be used in place of the analog compensator. The compensator is an analog computer designed to calculate the corrections necessary to maintain missile attitude and flightpath to the target. The digital compensator is very similar to an onboard flight computer. It was to be ready for use by June or July 2003.

The guidance system for the Al Samud II provides outputs to the control system that provide corrective signals to the 4 graphite jet vanes, redirecting the

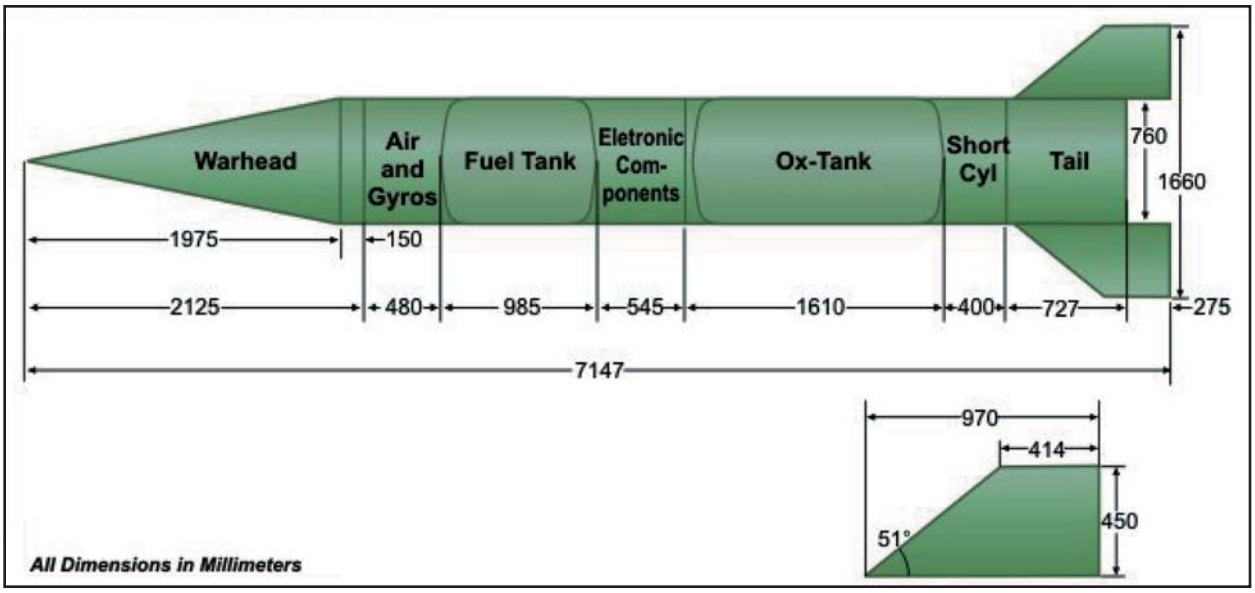

Figure 1. *Al Samud II diagram.*

Figure 2. *Al Samud II.*

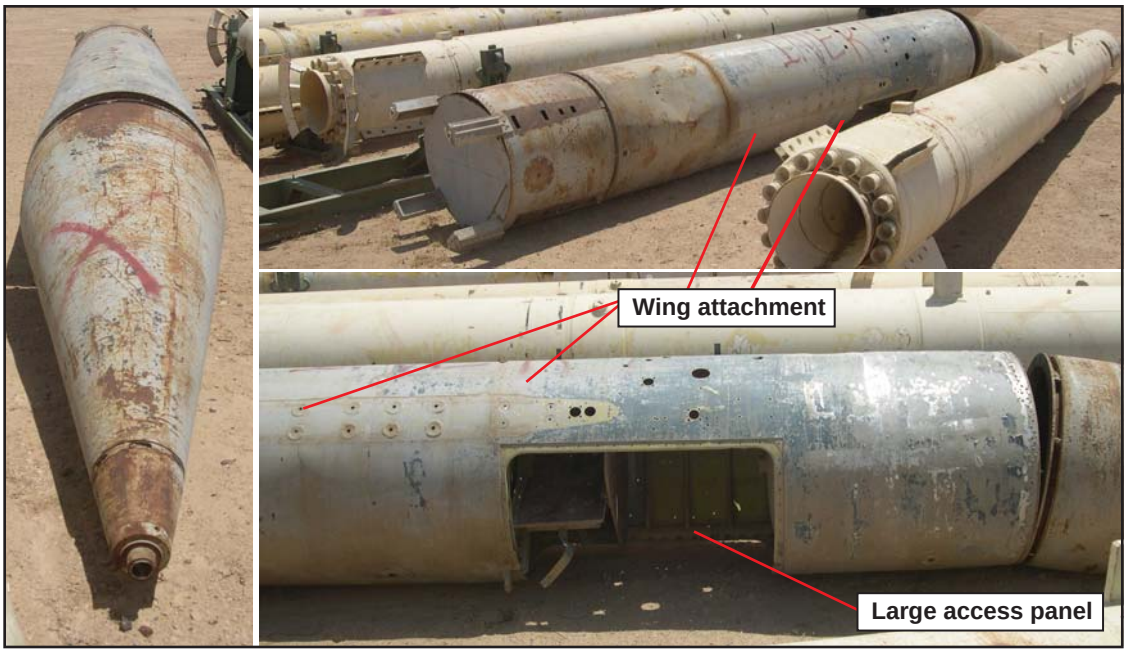

Figure 3. *Early Al Samud II using HY-2 airframes.*

thrust vector of the modified SA-2 Volga engine. This arrangement, similar to the Scud, provides control in 3 axes, but only during the powered portion of flight. The missile reaches apogee as the powered portion of flight ends (approximately 83 seconds in the case of the Al Samud II). The missile is unguided after thrust termination and in a free-fall ballistic flight until impact. This limitation, coupled with the inaccuracies of the guidance and control system, resulted in large miss-distances.

A senior source at Al Karamah informed ISG of a developmental effort to improve the accuracy of the Al Samud II using aerodynamic controls on the inboard sections of the aft stabilization fins. A high-pressure gas bottle would be used to supply air pressure to drive pneumatic-controlled actuators that provide aerodynamic control throughout both the missile's powered flight and through reentry. This improvement in control would have been incorporated following the completion of the initial guidance testing, most likely entering testing as early as the end of 2003.

- Around 1999, Iraq was working to import new, modern, complete guidance packages from Russian and FRY entities.

- Iraq was intending to purchase Inertial Navigation Systems (INS), fiber-optic systems, and high-precision machinery for indigenous production of guidance and control components.

Iraq relied on foreign assistance to develop the Al Samud II program from its early beginnings. ISG has uncovered Iraqi efforts to obtain technical expertise and prohibited items from other countries.

- Russian experts contracted through ARMOS assisted with indigenous production as well as the interface between imported guidance systems and the Al Samud II missile.

- A high-level official admitted that Iraq received approximately 280 SA-2 engines through the Polish company Evax by the end of 2001, followed by an additional 100 engines from Al Rawa'a.

- According to a former high-level civilian official, Iraq brought foreign experts into the country to assist in its missile programs.

Although advancements in the Al Samud II program were achieved quickly, shortage of necessary components limited production. Several sources estimated the number of missiles produced and delivered to the Army by OIF. Because these accounts vary and are not fully supported by documentary evidence, ISG has compared these claims with earlier information to develop a potential materiel balance for the missiles. See Delivery Systems Annex for more details.

- According to a former high-level official, Iraq began serial production of the Al Samud II missile beginning in December 2001. The production goal was to yield 10 full missiles a month. ***ISG believes that, because of a lack of certain components, Iraq did not always meet this monthly quota, while in some months they may have surpassed it—the production was dependent upon their success at importing components.***

Iraq declared the Samud II system to the UN in its CAFCD in December 2002, disclosing the 760-mm-diameter along with an 83-second engine burn time. Additionally, Iraq admitted in its semi-annual monitoring declarations that the system had exceeded 150 km on at least 13 occasions during flight tests. Because of this, UNMOVIC Executive Chairman Hans Blix, before the UN Security Council in December 2002, ordered Iraq to freeze all flight tests of the Al Samud II program until technical discussions could occur to determine the capability of the missile.

- According to a former senior official at Al Karamah, Iraq produced approximately 20 missiles during the first quarter of 2003.

- Another source claimed that, after UNMOVIC inspectors departed the country in March 2003, Iraq was able to assemble about 4 Al Samud II missiles from remaining parts that had been placed in mobile trucks to avoid air strikes. These missiles were not delivered to the Army.

Al Samud II Determined To Be an Illegal System

During a UN technical discussion in February 2003, an International Team of missile experts concluded that the Al Samud II missile had range capabilities well beyond the imposed 150-km limit. The UN then ordered Iraq to destroy the Al Samud II and associated support equipment specific to the system. UNMOVIC supervised the destruction of 72 missiles and 3 launchers in March. ***Due to the inconsistencies in source reporting and the lack of documentary evidence available, ISG has been unable to accurately reconcile the status of the Al Samud II inventory****. Refer to the Delivery Systems Annex for an assessment of the Al Samud II missile material balance.*

A missile requires a SAFF system to ensure that the warhead is safe to handle and remains unarmed until it has been launched, and then detonates when intended. After launch the SAFF system will activate the firing system and arm the warhead. Detonation of the explosive warhead charge is initiated by the fuze. Common fuzes used by Iraq include timer switches, accelerometers, barometric devices and impact switches (impact switches are either inertia [nose and tail fuzes] or crush [nose fuze only] and can be used as the primary fuze or as a backup to ensure detonation if other fuzing systems fail). For the Al Samud and Al Fat'h warheads, the impact or crush switch was located in the nose tip and activated by the impact of the warhead with the ground. The basic design of the high-explosive (HE) warhead was common between the two missiles and could be interchanged if needed with minimal modifications. The most likely composition of the explosive mixture was 60% TNT, 30% RDX, and 10% aluminum powder.

The submunition warhead developed for the Al Fat'h missile had an airburst fuze to ensure the effective dispersal of the submunitions (bomblets). The warhead contained up to 900 KB-1 anti-tank/anti-personnel (ATAP) submunitions.

Al Samud Warhead

ISG has not discovered any information to suggest that Iraq had considered or designed bulk-filled CBW warheads for the Al Samud. An impact detonation would be an inefficient method for disseminating chemical or biological agents, as the heat and

Iraqi Ballistic Missile Warheads

Iraq developed a unitary high-explosive (HE) warhead for delivery by both the Al Samud and Al Fat'h missiles. Iraq also developed a submunition warhead for the Al Fat'h and intended to develop a cluster warhead for the Al Samud.

Traditionally, the payload or warhead of a missile can be defined as an explosive or weapons package, the shell in which the weapons package is contained, and the Safe, Arm, Fuze and Fire (SAFF) system.

shock of an explosive detonation could destroy much, if not all, of the agents.

- Although ISG has recovered no evidence to suggest that "special" warheads were developed for the Al Samuds, the warhead is a direct extrapolation of the impact warhead design for the Scud and Al Husayn missiles and could be modified in the same way Iraq modified the Al Husayn HE warhead to produce crude CBW warheads.

- Iraq retained the intellectual capital for reproducing these kinds of "special" warhead designs, so modification and production of this crude type of warhead could be achieved in a matter of weeks with a relatively small team of specialized individuals.

The Al Samud I was designed to carry a unitary HE warhead, and Iraq apparently intended to develop a conventional submunition warhead for the missile. The Al Samud HE warhead is an extrapolation of the Scud warhead design and was later adopted for the Al Fat'h missile. Development of the warhead took about eight months and was completed in the summer of 1994. The Al Samud warhead components are listed in Table 2.

The original Al Samud warhead has a 500-mm-base-diameter and is 2 meters long with a design payload mass of 300 kg. The fuze mechanism is similar to that of the Scud missile. The original warhead design contained one forward booster and two rear boosters at the base of the warhead, one of which serves to provide uniform detonation in the system, the other as an auto destruct mechanism in case the missile deviates from its predetermined trajectory. Because Iraq lacked confidence in the accuracy of the guidance and control system, the backup and emergency boosters were never incorporated, leaving a single forward booster. An impact crush switch is incorporated into the graphite nose of the warhead (see Figure 4, Al Samud warhead design).

Iraq's desire to achieve 150-km range resulted in a quick modification to reduce the payload mass from 300 kg to 200-250 kg with 100-120 kg of HE, according to a senior missile official.

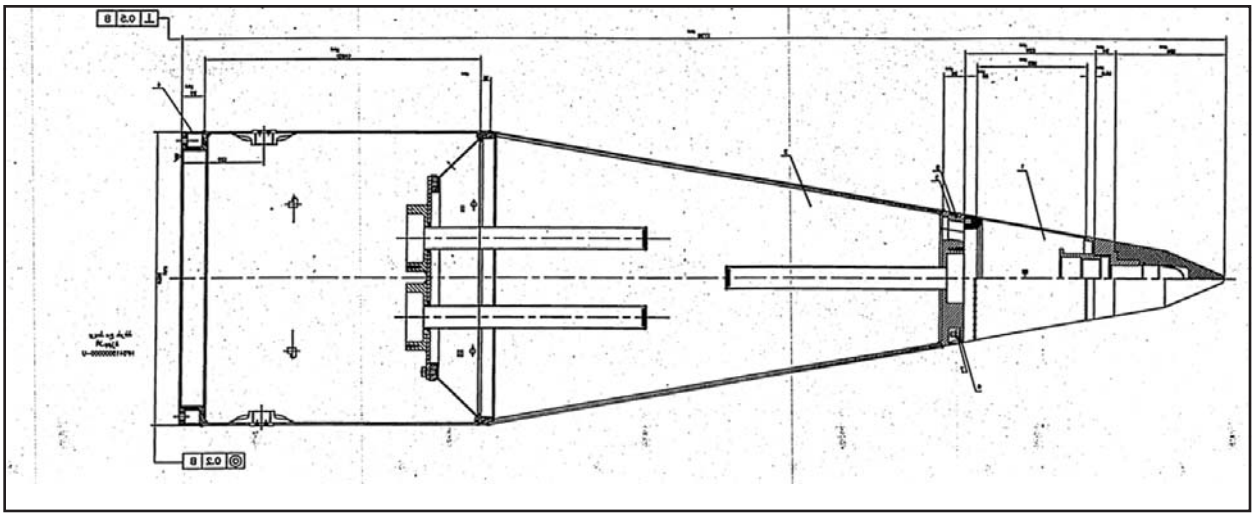

Figure 4. *Al Samud warhead design.*

Table 2

Nose Tip	Graphite
Outer shell	2-mm rolled steel
Insulation layer	3-mm Asbestos
Inner Shell	1-mm rolled steel
Fuze	Impact or crush switch housed in nose tip
Booster x 3	The third booster acts as a safety mechanism, detonating if the missile deviates from its predetermined trajectory
Filler	60% RDX, 30% TNT, 10% aluminum powder

- Iraq reduced the warhead mass by relocating the base plate and bulkhead forward into the warhead body, which reduced the available HE volume.

- Warhead modifications continued into 2001. A flight test in late 2001 used better constructed cylindrical and conical parts of the warhead with a payload of 240 kg and achieved a range of 151 km.

After succeeding with the unitary HE warhead, Iraq intended to develop a submunition warhead for the Al Samud, according to a senior Iraqi missile developer. However, no submunition warheads for either Al Samud or Al Samud II were manufactured.

Al Samud II Warhead

ISG has not discovered information to suggest that Iraq had considered or designed CBW warheads for the Al Samud II. The Al Samud II was designed to carry a unitary HE warhead, which is an extrapolation of the Scud and Al Samud warhead designs. At the end of June 2001, Al Karamah modified the Al Samud warhead to accommodate the increase in diameter from 500 mm to 760 mm. A design payload of 300 kg for Al Samud was agreed to with the UN, but the actual payload was 280 kg.

- Iraq manufactured a new warhead shell with a 760-mm-base-diameter and a length of 2,142 mm. The HE was housed in the forward section of the warhead and additional space reserved in the base for an air bottle that would provide pneumatics to control surfaces yet to be implemented in the missile fins (see Guidance and Control section). To compensate for the additional weight of the warhead shell and guidance system, the amount of HE was reduced.

- The booster for the emergency detonator was to be reinstalled, once confidence was gained in the guidance system. Figure 5 shows a schematic diagram of the Al Samud II warhead with gyroscope housings at the base of the warhead and notional emergency booster rod illustrated with dotted lines.

Within two weeks, Al Karamah produced a prototype that was tested at Al Qayyarah, a site belonging to the Air Force. The test successfully demonstrated the fragmentation and blast radius, resulting in design approval from the Army.

Between January and November 2002, Al Karamah and Al Qa'Qa'a conducted a study to improve the effectiveness of the Al Samud warhead.
The study was to investigate two aspects of the warhead:

- Methods by which the density of the explosive material could be increased; and

- How the blast effect of the warhead could be improved.

The theoretical filling requirements for the study of the Al Samud II warhead were:

- Total weight: 280 kg

- Explosive charge weight: 140 kg

- Warhead metal container weight: 140 kg

- Composition of explosive mixture: 60% RDX= 84 kg, 30% TNT= 42 kg & 10% AL= 14 kg.

Filling of the Al Samud warhead was a manual process; however, the study recommended that compressing the explosive material into the warhead by using a hydraulic press would improve the density and thus effectiveness and safe handling of the explosive material.

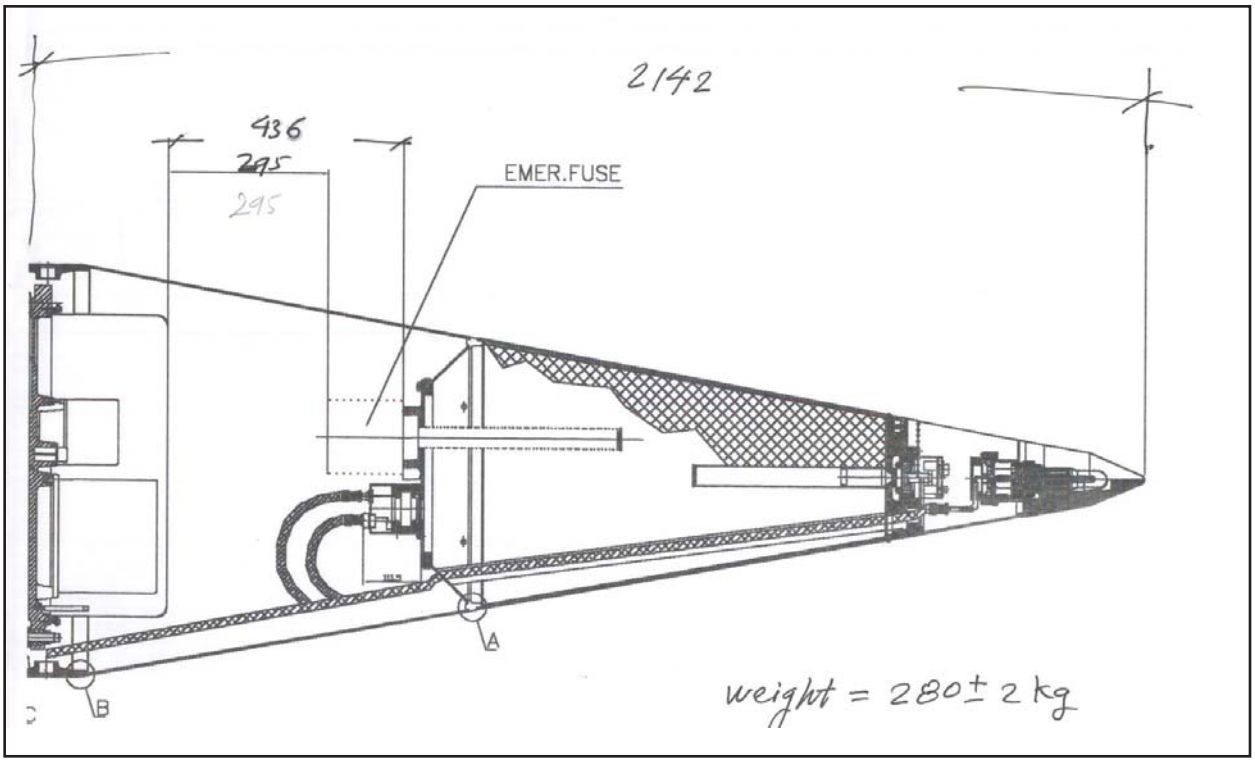

Figure 5. *Al Samud II warhead.*

Solid-Propellant Missile Developments

The Iraqi composite solid-propellant missile program that developed in the 1990s supported the development of a short-range ballistic missile (SRBM) system allowed within the UN limitations and the refurbishment of and improvement to existing weapon systems and attempted to support the development of ballistic missile systems prohibited by the UN.

Al Fat'h Missile Program

Background

Despite the limitations imposed by the UN sanctions and the international arms embargo, Iraq was able to produce and field the domestically designed Al Fat'h composite solid-propellant ballistic missile. The goal of the program, which commenced in June 1997, was to develop a missile that could deliver a 300-kg payload to a range of 150 km with an accuracy of 150 meters Circular Error Probable (CEP). The accuracy requirement for an unguided version of the Al Fat'h was 750 meters CEP.

- The Al Fat'h program began under the Ababil-100 project in the early 1990s. By 1994 the liquid- and solid-propellant missile development programs under Ababil-100 had split, and the solid-propellant program retained the Ababil-100 name. According to a senior Iraqi missile official, the first technical review meeting was held for the commencement of the Al Fat'h missile program in June 1997.

- The Al Fat'h was designed to carry unitary HE or submunition warheads. ***ISG has not found evidence to suggest the Al Fat'h was intended for use with chemical, biological, or nuclear warheads.***

Solid Propellants

Solid propellants can be divided into two classes: Double Base (DB) and Composite propellants.

- *DB propellants contain two primary ingredients: nitro-cellulose and nitro-glycerine. DB propellants can be extruded (Extruded Double Base—EDB) or cast (Cast Double Base—CDB) to form a variety of shapes.*

- *Composite propellants are a mixture of finely ground oxidizer (commonly ammonium perchlorate), fuel (commonly aluminum powder), and a polymeric binder (commonly HTPB). These ingredients are mixed and cast into the motor case. The motors spend days at elevated temperatures to cure the propellant, giving it the correct physical properties.*

Composite propellants have a higher combustion temperature and higher performance than that of the DB type. They are also safer but more complex to manufacture than DB propellants.

By the time of OIF, Iraq had produced between 100 and 120 Al Fat'h missiles, with up to 60 consumed in the development process. In late 2002, the Army had few alternatives and accepted the unguided Al Fat'h, with the understanding that the guided variant would continue to be developed. Between 50 and 60 missiles were provided to the Army, all of which were unguided; five were equipped with submunition warheads.

- During OIF, Iraq fired between 12 and 16 Al Fat'h missiles at Coalition targets, and between 4 and 13 missiles were damaged or destroyed by the Coalition. After the war the Coalition recovered at least 10 missiles, which leaves up to 34 unaccounted for missiles.

Al Fat'h development allowed Iraq to create and refine the technical expertise and develop the infrastructure needed to support the design and production of missiles with ranges beyond those allowed by the UN. The Al Fat'h design was conservative and used unnecessarily heavy airframe components, yet the missile reached and in some cases exceeded the 150-km limitation imposed by UNSCR 687 in flight tests and during operational launches.

- Computer modeling of the Al Fat'h provided an estimated range capability of 180 km. Using lighter airframe materials would improve the range.

Key elements of the Al Fat'h development process required foreign assistance or procurement. ISG has discovered that the guidance for the Al Fat'h was to consist of a "strap-down" inertial navigation system (INS) with gyroscopes and accelerometers, which would fall well beyond the production capabilities in Iraq. Also, key ingredients of the composite solid-propellant could not be produced in Iraq.

General Characteristics

The Al Fat'h missile (see Figure 6) was a solid-propellant ballistic missile weighing approximately 1,200 kg with an overall length of approximately 6.7 meters and a diameter of 0.5 meter for the main body and 1.4 meters with the aft fin assembly. While forward canards were used on a number of missile test flights, they were not used on the Al Fat'hs provided to the Army, and none have been noted on the Al Fat'hs captured to date.

- The airframe was primarily constructed from 4 mm thick 30CrMoV9 sheet steel. While 30CrMoV9 proved difficult to form, the extensive use of this alloy throughout the airframe simplifies missile construction. Although not available, maraging steel would have been the preferred material. The aft fin assemblies and nose cones were constructed of aluminum.

The Al Fat'h was designed to be launched from a Transporter-Erector-Launcher (TEL). Based upon the SA-2/Volga missile launcher, the Al Fat'h missile was mounted in a launcher-storage box with an integral launcher rail.

Propulsion

The Al Fat'h used a composite solid-propellant motor of conventional design and composition. According to a senior official in the Iraqi missile program, the final motor mass was 828 kg, although the motors varied from 820 kg to 856 kg because of variations in motor insulation. Other documentation retrieved by ISG

Rocket or Missile?

Although the Al Fat'h systems fielded with the Army and fired during OIF were unguided and therefore technically rockets, the Iraqi intent was to field a missile. Because of this ultimate goal, the Al Fat'h is referred to throughout this document as a missile.

give a propellant mass of approximately 770 kg. ISG believes that the variations in propellant mass suggest that the final design for the missile was not frozen. Manufacturing the Al Fat'h solid-propellant motor presented several challenges. Specifically, Iraq lacked preferred materials for the motor case and insufficient solid-propellant mixing capacity.

- ***Iraq lacked maraging steel sheets of sufficient size and quantity to manufacture Al Fat'h motor cases.*** Maraging steel has the advantage of being easy to form in its original state but, when annealed, provides excellent rigidity, strength, and crack resistance. Without maraging steel, the Al Fat'h motor case had to be constructed from 30CrMoV9 sheet steel (see Figure 7 for an Al Fat'h motor). Difficulties in forming and aligning the cylindrical shapes needed for the rocket motor cases from this material led to large miss distances, according to a senior official in the Iraqi missile program.

- ***Iraq lacked sufficient propellant mixing capacity.*** The mixers and bowls acquired in the late 1980s for the BADR-2000 program would have sufficed, but these were not available (see Infrastructure section). Instead, the Iraqis were forced to use four or five smaller 30-gallon bowls to mix the propellant needed for a single Al Fat'h motor, according to a senior official (see Figure 8). These bowls, using two mixers, were then poured sequentially into the motor casing. While one senior Iraqi official stated the process worked well, he also admitted one out of every 10 motors exploded during motor burn. The use of multiple bowls presented the potential for uneven curing of the propellant and inconsistent motor performance. In addition, this process also eliminated the possibility of multiple simultaneous motor castings.

Guidance and Control

The unguided Al Fat'h used simple aft stabilization fins. The guided version of the Al Fat'h would have had a relatively complicated control system, with canards, actuators, and a strapdown INS with an indigenously developed computer and imported gyroscopes and accelerometers. Iraq specified an INS accuracy of 1 degree per hour drift, which is relatively sophisticated. Iraq also considered using Global Positioning System (GPS) guidance.

- ***A highly accurate strap-down system, coupled with an adequate canard guidance system, would most likely have provided the Al Fat'h with the specified 150-meter CEP accuracy for the guided variant at a range of 150 km. That level of accuracy coupled with the submunition warhead would have made the Al Fat'h a formidable tactical delivery system.***

- The instrument/control section of the airframe, while of an unnecessarily heavy construction, is constructed using the same material as the rocket motor casing, thereby simplifying manufacture.

- The planned guidance package for the Al Fat'h would have broken new ground for Iraq by attempting to incorporate aerodynamic flight controls onto a ballistic missile. While a proven concept in some countries, this was the first attempt by Iraq to incorporate this type of control system into a ballistic missile.

- Iraq attempted to acquire Guidance and Control (G&C) components and technology from a number of foreign sources. Iraq reportedly received a sample inertial system from the FRY, but it was considered inadequate and of poor quality (see the Delivery Systems Procurement section for more details). There reportedly were 50 G&C sets delivered from Belarus prior to the start of OIF, according to a source with good access, although ISG has no confirmation this delivery actually occurred.

- Augmenting the Al Fat'h strap-down INS and canard controls with inputs from the GPS would have further increased system accuracy.

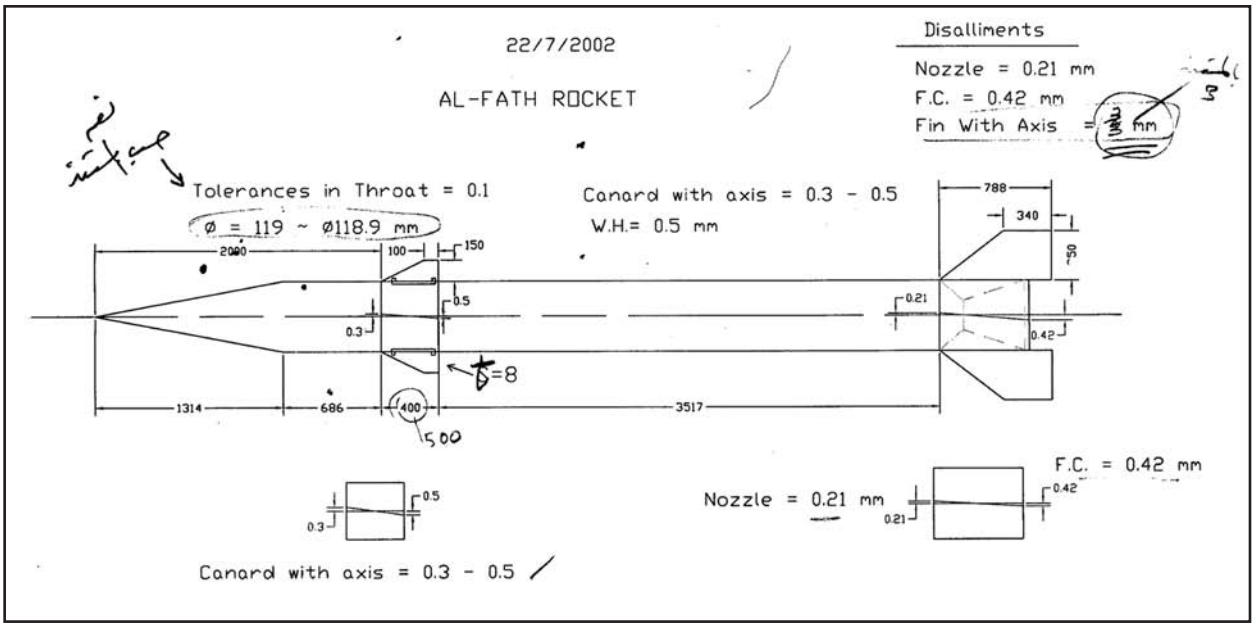

Figure 6. *Al Fat'h missile.*

Figure 7. *Al Fat'h solid rocket motor.*

Despite the lag in procuring the INS and testing delays, design work on the G&C for the Al Fat'h was well under way prior to OIF. Two guided flight tests were conducted prior to the war, one with roll control and a second with pitch control. ***According to a high-level official within the missile program, in March 2003, Iraq was only a matter of weeks from conducting a test flight with a full control system (equipped with INS and canards). ISG believes that Iraq did not conduct this flight test because, in December 2002, the UN had ordered that Iraq cease all missile tests until further notice.*** While this system would have used a prototype guidance system built from available components and be less accurate than desired, it would have allowed the Iraqis to validate the concepts and techniques.

Warhead

ISG has learned through debriefings of senior Iraqi officials that there were originally three warhead designs proposed for the Al Fat'h: a unitary HE warhead, a conventional submunition warhead, and a miscellaneous warhead initially suggested to be a Fuel Air Explosive (FAE) warhead. The army accepted both the HE and submunition warheads, but the FAE warhead was not pursued (see Figure 9).

- According to documents recovered by ISG, in 2002 the SSM Command presented a requirement for 100 guided Al Fat'h missiles, 20 of which were to be equipped with submunition warheads and the remaining 80 with HE warheads, to the Al Rashid General Company.

The Al Fat'h HE warhead was the same as the Al Samud HE warhead discussed earlier, which had been derived from the Scud HE warhead. Sharing the same missile diameter and interface as the Al Samud allowed for savings on production costs and facilitated the interchange of warheads, although the Al Fat'h warhead SAFF and arm circuit required adaptation due to the higher acceleration profile of the Al Fat'h during launch.

- The HE payload mass varied between 260 kg and 300-kg and contained 160-170-kg of HE. Figure 10 shows an X-ray of the Al Fat'h unitary HE warhead with a damaged impact or crush switch located in the nose tip.

Strap-Down Inertial Navigation System Tutorial

One of the major costs and maintenance factors in an inertial guidance system is related to the use of complex mechanisms required to control the attitude of the platform. If individual gimbaled gyroscopes are used, then this adds to the system error budget. One approach to eliminating these problems is the strap-down inertial guidance system.

In a typical strap-down system, the gyroscopes and accelerometers are mounted on a very rigid structure on the missile. Instead of using gyroscopes to keep the accelerometers pointed in a constant direction, a strap-down system allows the accelerometers to rotate with the missile and uses the gyroscopes to keep track of where each accelerometer is pointed. Because the accelerometers are no longer oriented along convenient reference axes, the mathematics become more complex; but, with digital computers, this is no longer the obstacle it once was.

Strap-down inertial guidance systems offer improved reliability, lower costs, and the potential for integration with other flight controls. The keys to strap-down performance are the gyroscopes and the software. Because of these characteristics, the strap-down inertial guidance system is ideal for short-range ballistic missile systems.

- The fuze, activated by the impact of the warhead on the ground, sends a firing signal to a booster charge, which in turn detonates the main explosive charge. Figure 11 shows the basic layout of the unitary warhead.

There is no evidence to suggest that unconventional warheads were to be developed for the Al Fat'h missile. However, as a direct extrapolation of the Scud conventional warhead design, the Al Fat'h HE warhead inherits the same primitive design that could allow modification to accommodate bulk-filled chemical or biological agents.

- Iraq retained the intellectual capital for reproducing the crude "special" warhead (CBW) design for the Al Husayn missile, so modification and production of this type of warhead could be achieved in a matter of weeks with a relatively small team of specialized individuals.

Figure 8. *30-gallon/100-liter propellant mixer bowl.*

Figure 9. *Al Fat'h unitary warhead in a shipping container.*

A senior Iraqi missile official indicated that submunition warheads were deemed to be more effective than unitary HE because they would have a larger lethal footprint and reduce concerns over poor missile accuracy. Iraq researched a variety of different configurations for the Al Fat'h submunition warhead before finally arriving at a design containing 850-900 submunitions.

- These submunitions were based on FRY anti-personnel/anti-tank KB-1 submunition identical to those used in the Ababil-50 submunition payload.

- The submunitions are stacked on top of one another and held in place by foam molds (see Figure 12).

The KB-1 submunition is an open-ended tube, housing a copper-shaped charge (see Figure 13). Upon detonation, the body fragments and scatters the ball bearings surrounding the outer shell, and the shaped charge fires, projecting the jet forward to penetrate the target. Typically, the submunitions contain 30 g of explosives.

- ***ISG judges that it is not possible to modify the KB-1 submunition to accommodate chemical or biological agents.*** Considering the small internal volume of the submunitions and risk of agent fratricide from the explosive charge, the KB-1 submunition is not a candidate for chemical or biological agent dissemination.

The shell case of the Al Fat'h submunitions warhead, manufactured by Al Rashid, was 3 mm thick and constructed of aluminum. The original design called for an aluminum warhead base, but the warheads produced used steel due to material shortages. The additional weight of the steel in the production warheads meant they could carry only 740 to 760 submunitions. Further, due to limitations in manufacturing technology, the warhead shell was conical rather than the aerodynamically optimum ogive design.

- Al Rashid General Company began Al Fat'h submunition warhead development in July 1998. Development continued through 2002, including five static tests, three of which were successful.

Iraq used detonator cord to fragment the warhead and let the airstream disperse the submunitions. Initially, Iraq wanted to use a single burster charge in the center of the warhead to disperse the submunitions after the detonator cord fractured the warhead and aerodynamic forces peeled back the skin. Experiments using a live burster charge were conducted in April and August 2002 and successfully dispersed 850 submunitions over an area of a 600-meter radius. During one flight-test, however, the burster failed to detonate. The airstream passing over the exposed submunitions dispersed the submunitions, and fewer munitions were damaged than experienced in previous experiments.

- As a result of this test, Iraq removed the explosive from the burster, but the empty burster tube was left in place to preserve structural support. Figure 14 is an X-ray of an Al Fat'h submunition warhead airshell. The black line running parallel with the sides of the warhead casing shows the detonator cord.

- Figure 15 illustrates the arrangement of the submunitions about the burster tube located along the central axis of the warhead.

Early attempts to use timing and barometric fuzes for altitude bursts of the submunition warhead failed. The problem was resolved (see Figure 16) by employing a diaphragm switch from the Scud barometric sensor and a battery from an Ababil-50 rocket.

In operation, the warhead is armed by the action of the "G" Switch through a sustained acceleration of 7.5 G for a minimum of 2.5 seconds. A barometric sensor detects altitude; when the missile ascends to a height of 5.5 km, a thermal battery is connected, charging the capacitors within the firing circuit. As the missile descends through 3 km, the capacitors discharge providing power to the detonator, which in turn initiates the detonation cord and the booster rod.

- In practice, the height of burst for submunition dispersal was approximately 2 km (2 km +/- 500 m), according to an official within the Iraqi missile program. Even with knowledge of the target terrain, such a loose tolerance is undesirable. (Figure 17 depicts an Al Fat'h missile with a submunition warhead.)

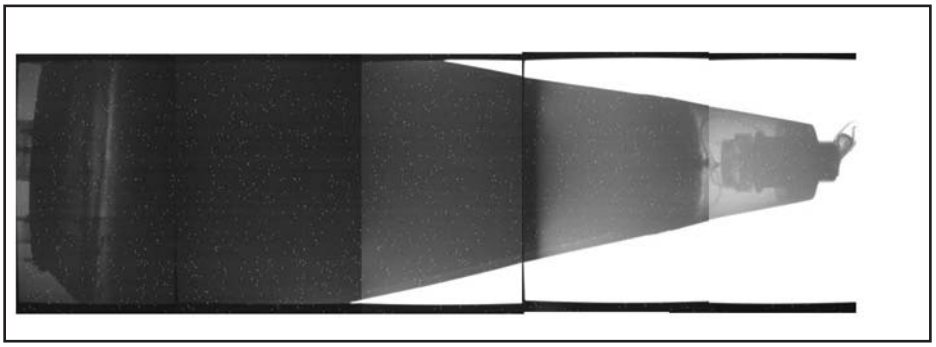

Figure 10. *X-ray of Al Fat'h unitary HE warhead.*

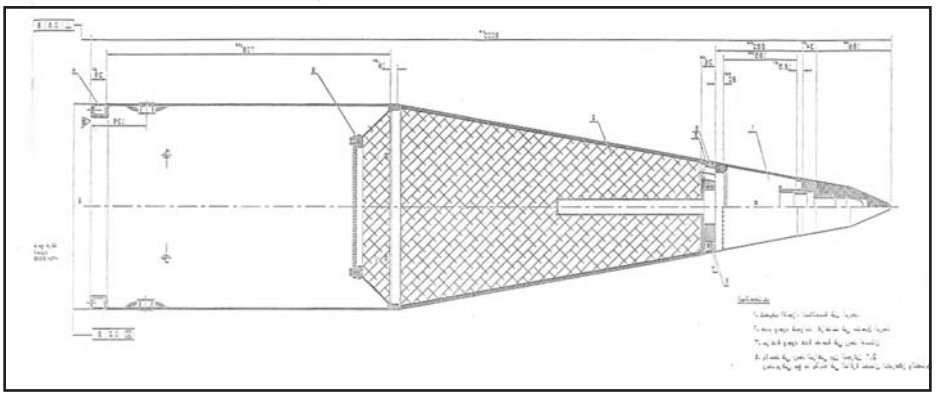

Figure 11. *Al Fat'h HE warhead.*

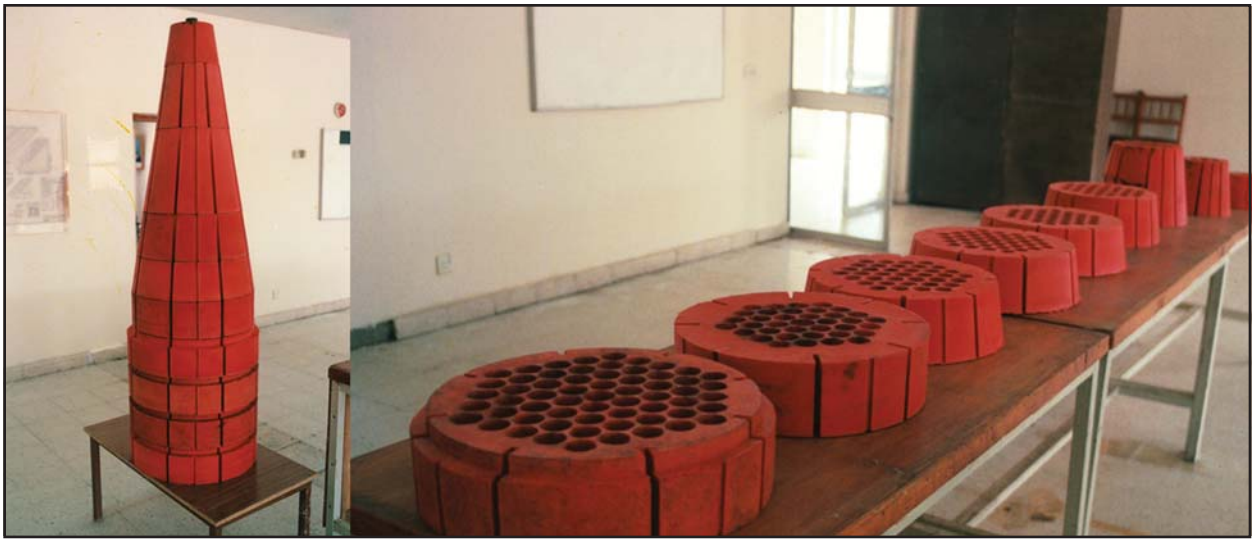

Figure 12. *Lightweight foam moldings used in the Al Fat'h warhead.*

Figure 13. *KB-1 submunitions.*

- Iraq intended to introduce a "strap-down" INS for the Al Fat'h missile in which presets that relate directly to predetermined burst altitudes (defined through time, velocity, and trajectory) could be configured before launch. Such a system has intrinsically greater accuracy in determining altitude than a barometric sensor.

Testing

ISG, through document exploitation and debriefings of senior Iraqi officials, developed a detailed accounting of the Al Fat'h test program. This test program, conducted between early 2000 and late 2002 consisted of approximately 50 individual firings, about 17 static motor tests and about 33 or 34 flight tests. A detailed breakdown of Al Fat'h missile launches and motor tests is included in the Delivery Systems Annex.

- Between 2000 and 2001, 10 or 12 solid-propellant rocket motor static tests were conducted at the Al Musayyib Solid Rocket Motor Support and Test Facility at Al Mutasim. Approximately midway through the static testing program, missile flight-testing began. This approach allowed modifications to the motor design to correct errors discovered during the flight-testing.

- The testing program passed through various phases as the emphasis shifted from motor performance and basic flight characteristics, to accuracy, reliability, and missile acceptance testing.

- Flight-testing began in 2000 and ended in late 2002. By mid-2001 to late 2002, Al Fat'h flight tests provided relatively consistent range performance using inert, submunition, and unitary HE warheads. The last two flight tests constituted the acceptance tests for the unguided variant of the missile.

- The flight-test program did have difficulties and never achieved the 750-meter CEP expected for the unguided airframe. The system also experienced a high failure rate during testing with 30% ending in failure and 10% of the motors experiencing catastrophic failure during firing.

Material Balance

While there are some firm production numbers for aspects of the Al Fat'h missile program, such as the number of missile flight tests, estimates for the total number of missiles produced and the number of missiles delivered to the Army vary widely. Captured Iraqi documents and other material provided by senior Iraqi personnel provide a breakdown of warheads, motors, missile airframes, and missile acceptance inspections for the years 2000 through 2002 (shown in Table 3). Based on these numbers, missile production probably was limited by Iraq's ability to produce rocket motors.

- While the figures reflect 95 missiles accepted by quality-control inspections by 2002, only 92 rocket motors had been produced. In addition, approximately 11 rocket motors were consumed in static testing for propulsion system development.

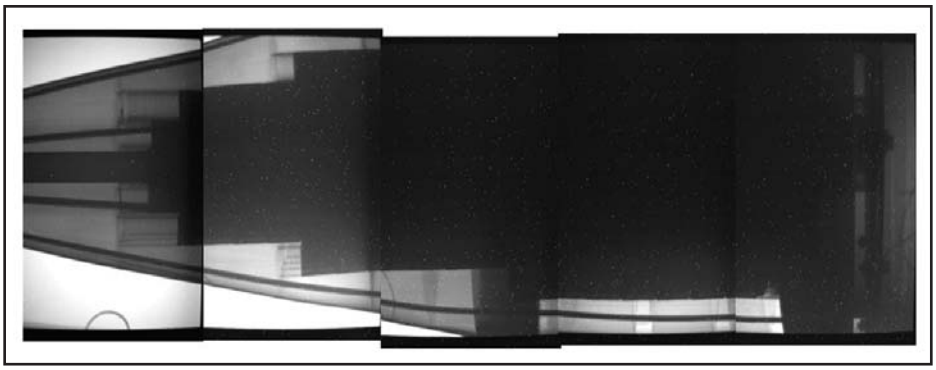

Figure 14. *X-ray of Al Fat'h submunitions warhead aeroshell.*

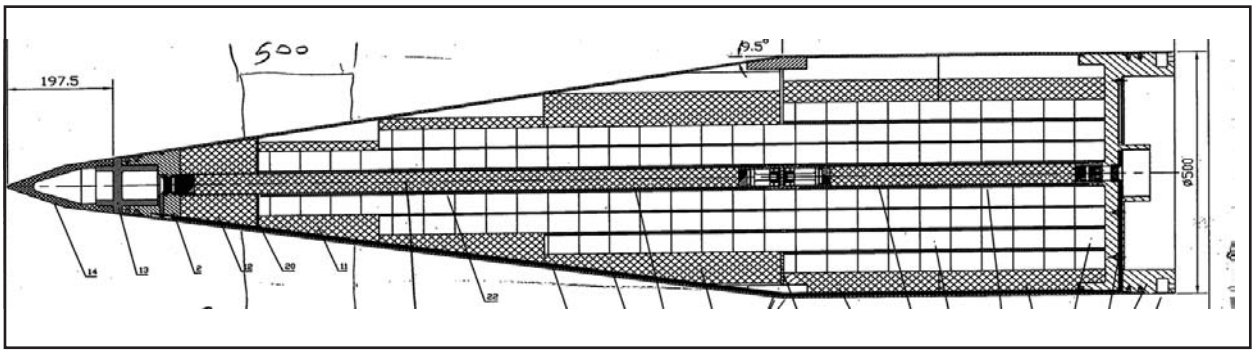

Figure 15. *Design drawing of the Al Fat'h submunition warhead.*

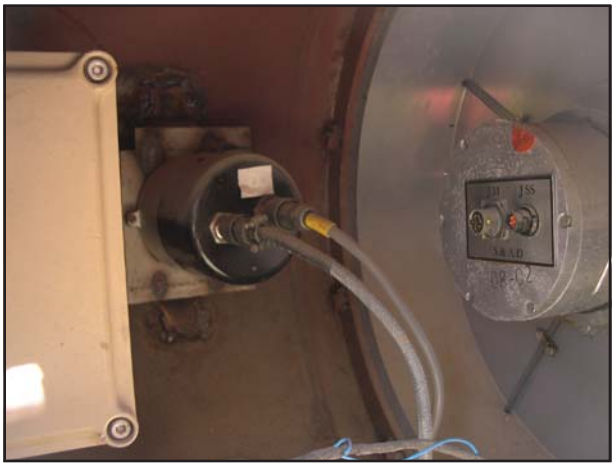

Figure 16. *Submunition warhead safe, arm, fuze, and fire system located at the base of the warhead.*

Figure 17. *Al Fat'h missile with submunition warhead.*

- The use of inert warheads in the early test flights may account for the relatively low number of warheads (79) produced from 2000 to 2002. Following OIF, several inert Al Fat'h missiles were found, probably used for troop training.

If true, Iraq produced about 80 combat-ready missiles by the end of 2002. Thirty-three or 34 missiles were consumed in test flights, leaving about 45-50 missiles available. During the first months of 2003, more missiles probably were produced, probably no more than one per week. ISG judges that between five and eight Al Fat'h missiles could have been produced in 2003, given the typical time associated with propellant curing and missile assembly, coupled with the interruption in production as Iraq dispersed material in anticipation of or in response to Coalition attack. Taking these assumptions together, ISG estimates Iraq had between 50 and 60 Al Fat'h missiles available at the onset of OIF.

- These numbers generally agree with those provided by senior officials within the Iraqi missile program, where the number of Al Fat'h missiles provided to the Army varies from as low as 30 to as high as 60. Of these, perhaps five to eight were equipped with submunition warheads.

- During the war, Iraq fired between 12 and 16 Al Fat'h missiles. In addition, informal assessments of Al Fat'hs destroyed or damaged during the war vary from four to 13. To date, Coalition forces have collected at least 10 Al Fat'hs.

- ***Given the above numbers, the number of Al Fat'h missiles unaccounted for could vary from 0 to 34 (see Table 4).*** However, ammunition and weapon systems are being collected and destroyed all over Iraq, and a number of Al Fat'hs have been misidentified as FROG-7 or ASTROS battlefield rockets. ***A full accounting of Al Fat'h missiles may not be possible.***

Table 3

Component	2000	2001	2002	2003	Total
Warheads	0	18	61		79
Motors	7	28	57		92
Airframes	13	31	66		110
Missile Accepted in QC Inspections	0	24	71	33 ?	95

Table 4

	Worst Case	Average	Best Case
Missiles Available to Army	60	45	30
Missiles fired	12	14	16
Missiles damaged/destroyed	4	8	13
Missiles Captured	10	10	10
Unaccounted for	34	13	0

Conclusions

The Al Fat'h was produced with materials allowed under UNSC resolutions, although a number of the ingredients in the Al Fat'h solid-propellant were subject to monitoring and verification under Annex IV of the Plan approved by UNSCR 715 (for a breakdown of specific propellant components listed in Annex IV, see the Delivery Systems Annex). Iraq attempted to acquire a number of these materials without the knowledge of the UN, and these efforts are noted in the Delivery Systems Procurement section.

The range capability of the Al Fat'h exceeded the 150-km limit imposed by the UN. A senior Iraqi official insisted the missile was designed to have a maximum range of 145 km with a 260-320 kg warhead, but, during flight tests between 2000 and 2002, the Al Fat'h flew beyond 150 km on at least eight occasions. The senior Iraqi official attributed the flights with ranges greater than 150 km to inaccuracies in the rocket motor insulation, resulting in greater than expected propellant mass.

- While Al Samud II tests with ranges in excess of 150 km were a factor in the UN's decision to require that missile's destruction, no decision by the UN had been made on the Al Fat'h prior to OIF.

- ***At least six missiles fired during OIF would have exceeded the 150 km range if not intercepted. The longest test flight declared by Iraq was 161 km, while the longest combat range probably would have exceeded this range.***

Al 'Ubur Missile Program

Background

The Al 'Ubur program probably began between 1999 and 2000 after UNSCOM departed and increased funding was available. The basic concept was to produce a SAM system, possibly modeled on the advanced Russian S-300 SAM. While Iraqi personnel reportedly gained access to the S-300, such a program was likely beyond Iraq's capabilities and the whole concept assumed an environment where there was no adherence to sanctions. According to one senior Iraqi,

The Al 'Ubur SAM is subject to a number of diverse spellings in its conversion from Arabic to English. While Al 'Ubur is used here, the system can be found referred to as Al Ibur, Al Ubour, Al Aboor, and a number of other variations.

the program involved not only the missile, but also radar, launcher, and ground support equipment. This initiative is evidence of Iraq's belief that it would be able to import the required materials almost at will.

Brigadier General Mahmud Tahir from the Al Rashid General Company headed the overall development effort. Other program officials from Al Rashid included 'Abd-al-Baqi Rashid Shia' Al Ta'i (DG of Al Rashid) and Brigadier Engineer Mar'uf Mahmud Salim Al Jalabi (DG of Al Fat'h General Company). The Al Fat'h General Company was responsible for the solid rocket motor and the airframe designs, including the warhead, fuze, structure, aerodynamics, as well as the G&C system. The Al Milad General Company was responsible for the development of the radar. The Al Fida' General Company was responsible for the launcher.

While some Iraqi officials have stated the Al 'Ubur program was intended to produce a SAM, the potential for use as a SSM has been acknowledged by senior Iraqi missile officials.

- Based on the proven Al Fat'h solid-propellant motor, the Al 'Ubur would have used a solid-rocket motor with the same diameter, but one meter longer than the Al Fat'h. While the Al 'Ubur motor would have had a different thrust profile optimized for use as a SAM, the Al 'Ubur most likely would have exceeded the 150-km limitation of UNSCR 687 if used as an SSM, according to a few officials in the Iraqi missile program.

- Because the Al 'Ubur and Al Fat'h solid-rocket motors would use the same propellant mixture, creation of an Al 'Ubur motor optimized for an SSM role would have only required the creation of a different mandrel to optimize the thrust profile.

- Flight-testing of an Al 'Ubur SAM would have provided relevant performance data if the missile was to be used in an SSM role.

Based on reporting disclosures about the development of the Al 'Ubur, ISG judges that, Iraq most likely intended to modify the Al 'Ubur motor, once developed, for use in an SSM mode. Based on its previous success in converting the SA-2/Volga into an SSM, Iraq possessed the techniques required to undertake such a project.

Propulsion

The Al 'Ubur solid rocket motor was the major system component furthest along in development by the time of OIF. The Al 'Ubur motor was effectively an Al Fat'h motor with its length extended from 3.5 to 4.5 m. It had the same 500-mm diameter, propellant formulation, and steel case material. The Al 'Ubur had a different wagon wheel grain design to provide a different thrust profile and a different nozzle optimized for a SAM, compared to the 3-point star configuration in the Al Fat'h, according to a senior program official.

- The Al 'Ubur thrust profile failed to meet the calculated thrust, but the motor was considered more "stable" than the Al Fat'h motor, according to the same official.

Guidance and Control

Given the ever-decreasing effectiveness of sanctions, Iraq was able to consider bolder steps in areas where it still had technical difficulties. If the sanctions regime remained strictly enforced, there would have been little or no effort by Iraq to address these shortfalls. The Al 'Ubur design called for a strap down INS that would be provided by a Russian company and an integrated radar seeker for terminal guidance, but the entire G&C system was never prototyped. The Soviet R-40 (AKRID/AA-6) AAM was used for simulation and parts.

- The Al 'Ubur SAM system would have been an extremely complex system with an integrated radar seeker, phased array radar, and controlled via communication uplinks and downlinks embedded into the radar waveforms. The communication links and the radar were to be designed by the Al Milad General Company.

According to an official within the Iraqi missile program, an unnamed Russian company was to provide eight Fiber-Optic Gyroscope (FOG) INS systems; four would go to Al Karamah and four to Al Milad. Four ring laser gyroscope (RLG) INS systems were also to be provided and equally divided between Al Karamah and Al Milad. Al Karamah received up to seven FOG systems by the second-half of 2002.

ISG judges that this information may be in error because use of a full INS on a SAM is not required. It is more likely that this information is associated with Al Fat'h or Al Samud II as specified by another source.

Warhead

The Al 'Ubur SAM was designed to carry a fragmentation warhead weighing 176 to 180 kg.

Testing

Al 'Ubur motor testing began using an intermediate subscale motor contained in an Ababil-50 motor case. These tests had mixed test results, using various propellant grain designs. Full-scale motor testing probably began in 2002, but reports vary on the actual start date.

- One senior official reported that a successful full-scale test was conducted on 12 January 2002.
- Another official reported that full-scale testing was conducted from approximately June to November 2002.

Following the successful static tests, Iraqi officials discussed using the Al 'Ubur in an SSM role, although no formal actions were taken. Range calculations produced a variety of results.

- One calculated range is given as 220 km and a second gives a range of 206 km, according to two officials involved in the Al 'Ubur program. Details of the missile configurations used in these calculations are unknown.
- There were no flight tests of the Al 'Ubur, and activity on the program ceased with the beginning of OIF.

Conclusions

The manufacture of a modern phased array-based SAM system would have been a daunting challenge for Iraq, even with access to Russian technical specifications. ***Exploitation of captured documents, however, indicates development of the SAM elements of the Al 'Ubur program by the end of 2002.***

The potential use of the Al 'Ubur SAM as a long-range ballistic missile is clear, and high-level officials in the program indicated they had considered using the Al 'Ubur as an SSM. The similarities in the proposed rocket motor and INS indicate an Al 'Ubur SSM could be developed quickly, but such development could be detected during the inspection process. Further, given the longer motor and potential for lighter materials, an Al 'Ubur SSM would certainly have exceeded the 150-km limit imposed by the UN. ISG judges that elements of the Al 'Ubur SAM program were well beyond Iraq's manufacturing capabilities.

Other Composite Solid-Propellant Systems

By the late 1990s, Iraq had a number of rocket systems that had reached the end or exceeded their shelf life and needed refurbishment, including the FROG-7 (LUNA), Ababil-50, and some SAMs. ***Iraq was not able to acquire replacement systems from abroad or get help for the refurbishment effort; it had to rely on domestic capabilities***.

In 2000-2001, Iraq began a "re-motor" project to extend the shelf life of its FROG-7 (LUNA) and Ababil-50 battlefield artillery rockets by replacing their aging double-base solid rocket motors with more energetic composite solid-propellant motors. Renamed Al Ra'ad and Al Nida', respectively, these efforts helped advance the composite solid infrastructure in Iraq. It is unclear if these projects were completed by the time of OIF.

- Composite propellants offer higher energy than double-base propellants, so the re-motor effort renewed the shelf life and improved performance of the rockets.

Long-Range Ballistic Missile Projects
United Nations Security Council Resolution (UNSCR) 687 restricted Iraq's delivery systems to ranges not in excess of 150 km. Further, UN sanctions and rigorous UNSCOM inspections were a serious constraint to Iraq's missile research and development programs. Though unable to overtly develop long-range missile projects, compelling evidence suggests that Iraq, in order to reach targets like Tel Aviv and Tehran, never abandoned its interest in delivery systems with ranges well beyond 150 km. ***Husayn Kamil's flight to Jordan effectively ended all work on long-range missiles until the efforts were reconstituted after 1998.***

- A senior Iraqi missile engineer stated that the subject of long-range missiles (i.e., missiles with ranges greater than the 150 km) was not raised again until 1997/98 at a monthly ballistic missile meeting chaired by Huwaysh at MIC. At the meeting, Huwaysh reportedly stated his desire for a 1,000-km missile.

- According to Kamal Mustafa "Abdallah Sultan Al Nasiri, the former Secretary General of the Republican Guard, Huwaysh in the summer of 1999 gave a speech to the Republican Guard and SRG audience in which he stated that Iraq was developing a missile with a range of 500 km and that it would take five years to develop.

- At a June 2000 meeting, Saddam ordered Huwaysh to develop a missile with a range greater than the range of the Samud II, according to a senior official within the Iraqi missile program.

Clustering SA-2/Volga Engines Designs

ISG has retrieved copies of Iraqi design drawings for two long-range missiles, one based on a cluster of two SA-2/Volga engines and the other based on a five-engine cluster. Although dated 23 August 2000, the drawings are not signed and therefore the name of the draftsman or designer is unknown. ***Despite extensive research, ISG has not determined a single, clear explanation of the events leading up to and since the date of these drawings, but Iraqi interest in***

Historical Projects

Iraq has a history of studies, research, development, and production of various long-range ballistic missiles. Much of this work found its way into more recent studies.

Al 'Abid (1989)

By 1989, Iraq had designed, manufactured and tested the first stage of a three-stage space launch vehicle. *The first stage was a cluster of five Scud-variant missiles. Although the vehicle failed after 45 seconds, it proved a successful technology demonstrator for generic clustered designs.*

- *The test achieved multiengine ignition, thrust build-up, release, and controlled ascent during part of the first stage trajectory. At about Mach 1, the aerodynamic stresses overcame the control authority and the missile inter-stage collapsed, according to an interview with a senior missile official and an UNSCOM report. According to senior Iraqi officials, Iraq continued studying clustered Scud engines for a year after the Al 'Abid failure, ceasing in 1991.*

Multistage Launch Vehicle Simulations (1990-95)

In 1991-92, Iraq conducted flight simulations of a three-stage missile incorporating Scud-type missiles, according to material obtained by the UN. *According to an Iraqi official, this was a theoretical study that included trajectory calculations for several clustered SA-2 engine configurations. The configuration was different from that of earlier work conducted on Al 'Abid.*

In 1993, Iraqi engineers were ordered to design a turbopump capable of simultaneously feeding a cluster of four SA-2 engines. *Although no turbopumps or engine clusters were produced, the concepts were well understood.*

At the end of 1994 through early 1995, Iraq performed studies for multi-stage launch vehicles using performance parameters derived from clustered SA-2 engines. *The configurations studied would have exceeded 150 km.*

designs containing clustered engines can be traced back at least as far as 1989. See Figure 18 for design drawings.

- One design uses a two-engine cluster mounted in a flared engine bay that supports a 760-mm-diameter airframe. Iraqi experts have assessed the range of this version to be at least 500 km. The propellant tanks, pressurization system, G&C, and warhead of this concept would be common with the 760-mm Al Samud II ballistic missile.

- The second design uses a five-engine cluster mounted in a flared engine bay that supports a 1,250-mm-diameter airframe. Iraqi missile experts assessed this design would reach a range of at 950-1,000 km.

Various sources have provided ISG with differing timelines of events for the clustered engine project pursued by Al Karamah, but most sources suggest the order to develop long-range missiles came in 2001. The chronology of events that led to the creation of these designs is unclear.

- According to an engineer within the Iraqi missile program, Huwaysh ordered work to start on an initial design of a long-range missile on 15 November 2000 following the first successful flight test of a modified 500 mm Al Samud. The engineer added that this work was completed in April 2001.

- The same source later stated that Huwaysh ordered the design work to begin in August 2001 and requested detailed design to commence the following month.

- According to another senior missile official, Huwaysh instructed Al Karamah in July 2001 to start work on long-range missiles.

- Huwaysh insisted that, at a meeting with Saddam at the beginning of 2002, Saddam ordered him to create a missile with 750-km range and that it was expected to be ready in six months.

Though the dates on the actual design drawings obtained by ISG suggest they were created in August 2000, other information suggests that modifications were made throughout 2001. Source reports provide conflicting accounts as to when they were actually completed.

- Designs for the two-engine and five-engine missiles were delivered to Huwaysh in December 2001 or January 2002, and all work on these was completed in January 2002.

- A high-ranking MIC official reported that these designs were completed in March 2003.

- In July 2002, Huwaysh ordered that all documents pertaining to the long-range missiles be returned to him. He said that Muzhir brought him two boxes of documents in December of that year. However, other documentation not forwarded to Huwaysh had been recovered by ISG.

- Huwaysh ordered all the documents on the long-range missile project be destroyed at the onset of OIF, according to several high-level officials in the Iraqi missile program.

The evidence collected by ISG suggests Iraq had not completed the designs by the time UNMOVIC entered Iraq, although sources vary on the timing of the design work. Many sources refer to the project as being highly secretive with information being passed only in person at face-to-face meetings among a select few individuals, which may account for discrepancies in dates provided by individuals without direct access. Figure 19 depicts the timeline of missile developments.

ISG's confirmation that Iraq was working on designs for long-range clustered-engine missiles, although this work never progressed beyond the design phase, is evidence that the Regime was covertly researching the development of missiles with ranges in excess of 150 km. Further, Iraq took advantage of existing Al Samud II designs and had begun to develop the infrastructure that could have led to rapid development of these concepts.

- ***The use of a 760-mm-diameter airframe could allow the use of Samud II jigs and fixtures to support the two-engine cluster design. ISG judges that it could provide a good concealment mechanism for work on prohibited programs.***

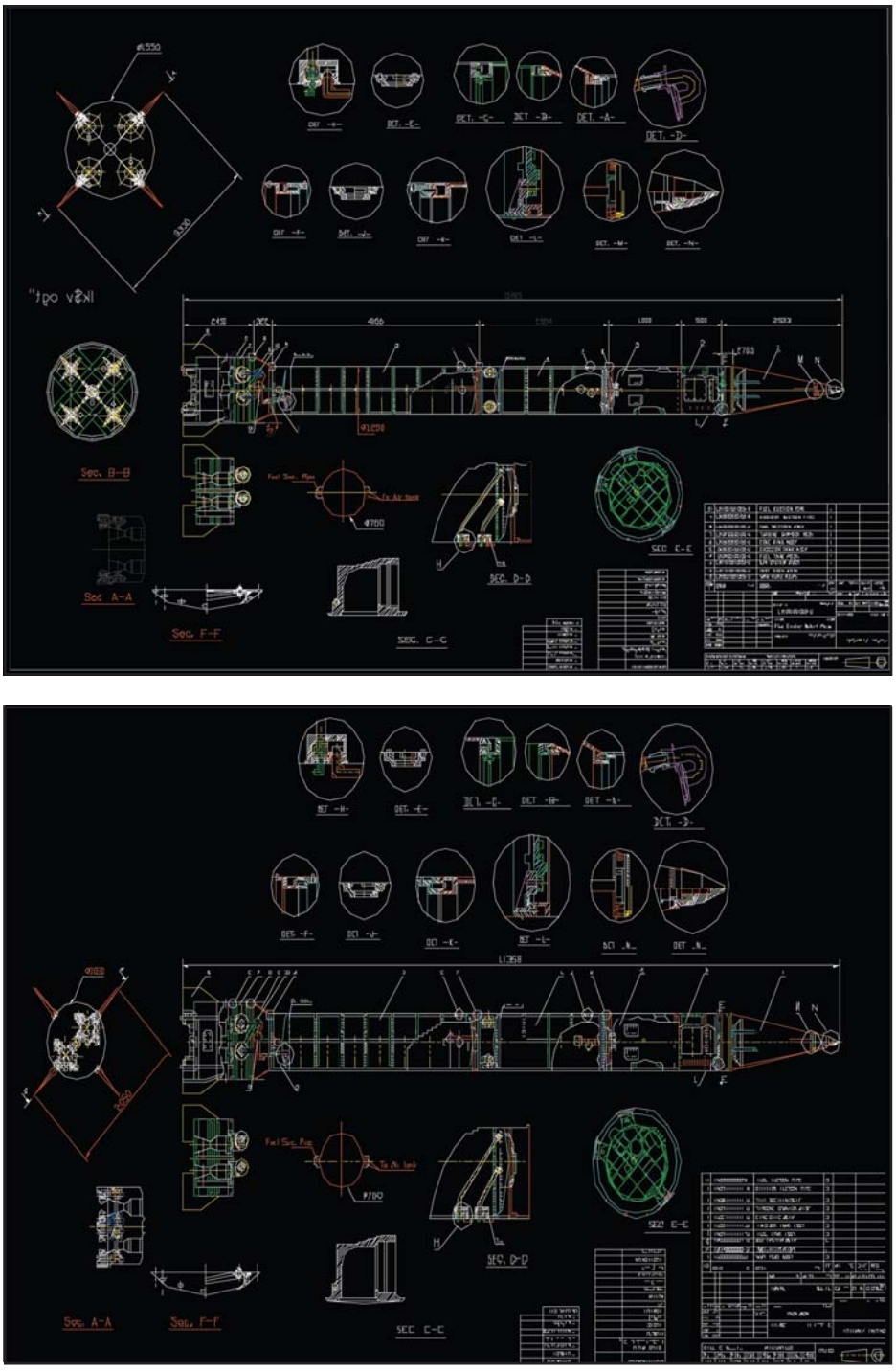

Figure 18. *Design drawings for two-and five-engine cluster missile.*

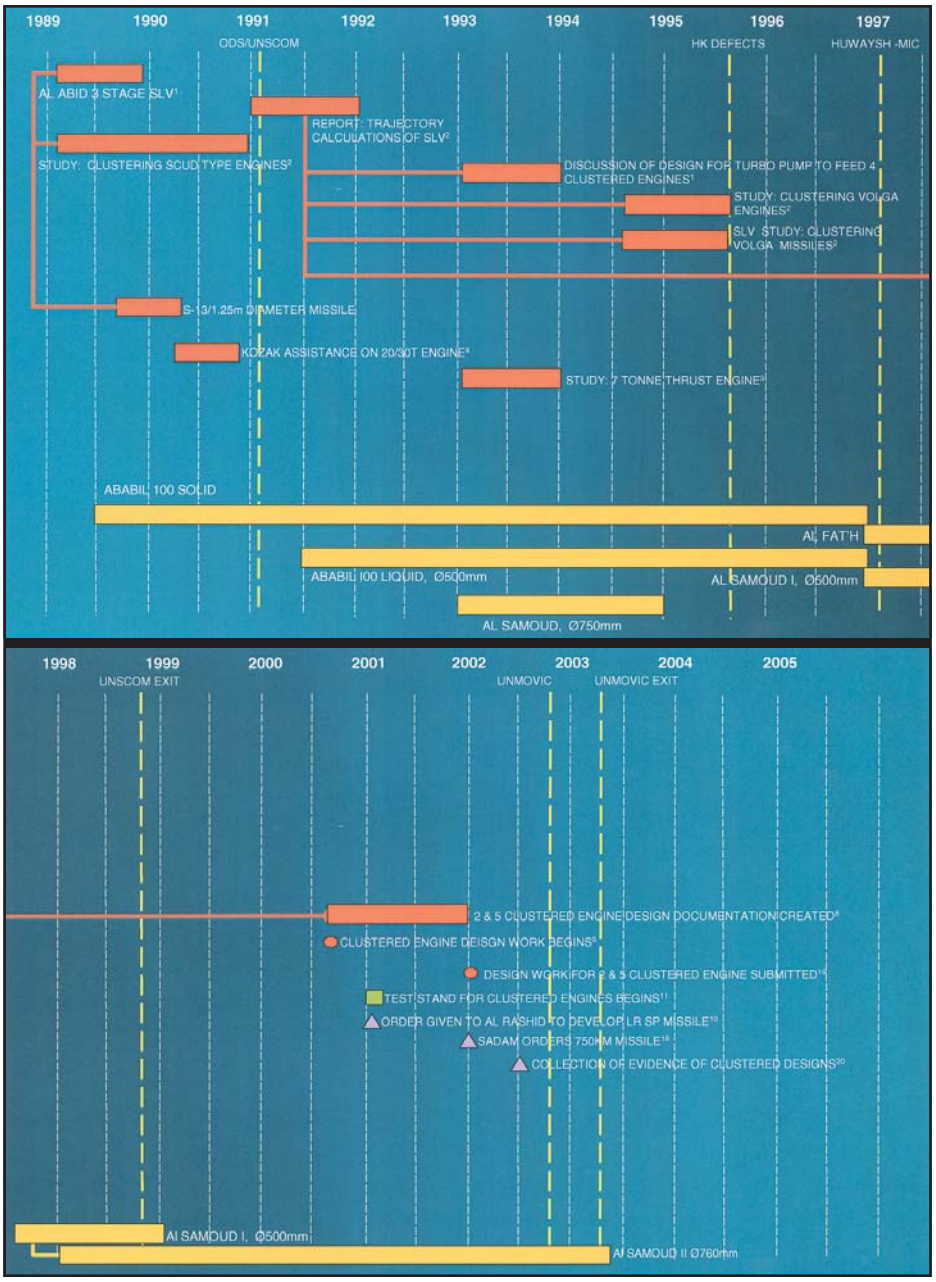

Figure 19. *Liquid-propellant long-range missile chronology.*

- The new test stand at Al Rafah was much larger than the preexisting engine test stand and could have been modified for testing clustered SA-2 engines. According to one Iraqi engineer, work on the new stand began by August 2001, suggesting that the requirement for the facility must have been drawn up much earlier.

- Statements by various sources indicate that, before OIF, Iraq had over 200 SA-2 engines that had been scavenged from damaged missiles. Adding to this, at least 380 engines imported from Poland and possibly Russia or Belarus were more engines than probably required to immediately support the Al Samud II program. ***Some of these engines could have been available for use if Iraq had moved forward with a clustered-engine development program.***

SA-2 Conversions to Surface-to-Surface Missiles

Numerous sources involved in Iraq's missile program have admitted to ISG that from 1997 until 2003 Iraq had several undeclared programs to convert SA-2 SAMs into SSMs with maximum ranges from 250 km to 500 km. Though ISG has not been able to confirm these claims, source interviews indicate that Iraq pursued at least four projects.

- According to a missile program official, in approximately 1997 (while UNSCOM were monitoring in-country), Iraq initiated an effort to convert the SA-2 into an SSM with a range of at least 300 km. Iraq conducted two tests in late-1997 or early-1998 along depressed trajectories so that they would not exceed 150 km. Iraqi officials assessed, however, that the missiles were capable of reaching 300 km but with poor accuracy. Work on this program ceased and the only retained documentation consisted of range calculations for the missile at various launch angles. ***ISG has yet to recover these calculations.***

- Three missile officials from Al Kindi disclosed information about the Sa'd project, which began in 2000, to convert the SA-2 into an SSM with a theoretical range of 250 km. A MIC committee decided to withhold this information from the UN because the project had not yet reached the prototype stage, and all documentation was removed from Al Kindi prior to the return of UN inspectors in 2002.

- The missile program official also knew of another project initiated in 2001 or 2002 after a study by 'Ali 'Abd-al-Husayn who was later transferred to work at the NMD. The source had no other information about this project.

- The final project was initiated either immediately before or during OIF, according to an Iraqi scientist. This was a 'crash' project under the control of Al Milad General Company and discussed at MIC during a meeting on 15 March 2003. The project converted two SA-2s into SSMs, but Iraq was unable to flight test them due to the speed of the prosecution of the war, according to a senior official within the Iraqi missile program.

In all cases, from the evidence collected to date, Iraq had not undertaken the wholesale conversion of SA-2 missiles to SSMs, and ISG has uncovered no evidence that payloads designed for these missiles would be anything other than the original HE warheads.

Large-Diameter Solid-Propellant Missile Project

In 2000 or 2001, Iraq began development efforts toward a long-range, solid-propellant ballistic missile that would, when fully developed, greatly exceed the 150-km-range limit imposed by UNSCR 687. Further, the program appears to have been highly compartmented and virtually undocumented. Destruction of infrastructure previously associated with prohibited programs in accordance with UNSCR 687 effectively limited Iraq's pursuits to research and development efforts.

Program Development

Iraqi desire for a long range, solid-propellant ballistic missile system in 2000-2001 can be traced to the BADR-2000 program from the mid-1980s. This program would have produced a two-stage, 750-km-range ballistic missile system using a 0.8-meter-diameter solid-propellant motor as the first stage.

Reports vary, but, beginning in 2000-2001, and maybe even earlier, Iraq again decided to pursue a long-range solid-propellant missile.

- Starting perhaps as early as 1998 or in 2000-2001, Huwaysh ordered the design of a long-range solid-propellant ballistic missile according to several senior missile officials.

- According to Huwaysh, in early 2002, Saddam ordered the construction of a missile with a minimum range of 650 km. Huwaysh then directed Dr. Muzhir Sadiq Saba' Khamis Al Tamimi and 'Abd-al-Baqi Rashid Shia' Al Ta'i to conduct feasibility studies of such a missile, one as a liquid and one as a solid.

Although it is unclear when the program started or what the range requirements were, Huwaysh in 2000 or 2001 formed a small, select Large Diameter Missile (LDM) committee and reportedly tasked the committee with developing a 400-km-range solid-propellant ballistic missile, according to senior Iraqi missile officials.

- One senior Iraqi official reports the committee consisted of Huwaysh, 'Abd-al-Baqi Rashid Shia' Al Ta'i (DG of the Al Rashid General Company), Mar'uf Mahmud Salim Al Jalabi (DG of the Al Fat'h General Company), Muzahim (probably Staff Lt Gen Muzahim Sa'b Hasan Muhammad Al Nasiri, Senior Deputy to the MIC Director), and Muzhir Sadiq Saba' Al Tamimi (DG of the Al Karamah General Company).

- There are conflicting numbers for the required range of this missile. Various high-ranking former Iraqi officials have offered range requirements of 400 km, 500 km, at least 650 km, 400 to 1,000 km, 500 to 1,000 km, 1,000 km, or 1,000 to 1,200 km. Further, a payload of 500 to 1,000 kg was mandated, depending on the source of the reporting.

By the late 1990s, Iraq's composite, solid-propellant ballistic missile capabilities were centered in the Al Rashid General Company and the Al Fat'h General Company, but only Al Rashid pursued development of the long-range missile. According to a senior missile official from Al Rashid, Huwaysh ordered the development of a solid-propellant missile with a range of at least 600 km carrying a payload of 500 to 1,000 kg.

- According to senior Iraqi officials, there were no written records of the development effort, and all affected computer hard-drives were reformatted prior to the return of UN inspectors in 2002.

- While it appears that only one long-range solid-propellant development effort was pursued, the compartmented nature of the program led some Iraqi officials to believe there may have been multiple efforts.

- The solid-propellant development effort undertaken by the Al Rashid General Company was augmented with personnel from the Al Fat'h General Company and other MIC entities including Hashem 'Abd Al Muhammad of Al Amin factory, Brigadier 'Abd-al-Hamid of Al Karamah (warheads), Al Jalabi of Al Fat'h (propellant), and Brigadier Hashim of Al Fida' General Company (launcher).

- A senior Iraqi official stated the Al Rashid-based design effort consisted of 'Abd-al-Baqi, Dr. Sa'd Tami Hamidi Al 'Anbaki (Chief of the Engineering Department), Sadday Ibrahim (Engineer), Dr. Sa'd Mahmud Ahmad (Propellant Chemist), and Sa'd Muhammad (senior Al Rashid official). According to this source, Al Rashid was pursuing a 600-km-range missile.

The Al Rashid effort went forward in 2001. The initial concept based on a cluster of three Al Fat'h motors was rejected because of modeling limitations. The selected design consisted of a 0.8- or 1.0-meter-diameter motor that may have been based on the BADR-2000 design.

- The design reportedly would involve a missile 6 to 7 meters long with an accuracy of 2% of the range flown for a spin-stabilized version and 3 to 5% for an unguided version.

- The solid rocket motor would have had a propellant mass of 4,000 to 5,500 kg as compared with an Al Fat'h motor propellant mass of 828 kg.

Al Rashid moved forward with rocket motor development efforts. Iraq attempted to use a barrel section from the Supergun project to create a prototype 1.0-meter-diameter motor case, but the effort failed because of material incompatibilities when Iraqi technicians were unable to weld the Supergun section to the motor end domes.

- All associated materials were either destroyed prior to the arrival of UNMOVIC in 2002 or reused as motor casting chambers.

- ***Most of the reporting on this development effort does not specify the type of warhead envisioned, with two exceptions. One senior Iraqi specifically stated the missile was developed for a chemical payload, while another - specifically stated the warhead would be high explosive. ISG found no evidence to support either claim.***

While Al Rashid was pursuing the long-range design, a senior Al Rashid official apparently had doubts that it could be completed. Although he reportedly never formally stated the missile could not be developed, he apparently did inform Huwaysh sometime in 2001-2002 of limitations in Iraq's solid-propellant infrastructure, stating that a missile with a range of 650 km would require 5.5 tons of propellant. Huwaysh reportedly informed Saddam Husayn.

- Although still limited, Iraq had made substantial infrastructure improvements that would have improved its ability to manufacture large motors. At least one of the 300-gallon propellant mixers "destroyed" by UNSCOM was repaired; Iraq tried, unsuccessfully by the time of the return of the UNMOVIC inspectors, to repair the second. In addition, casting pits, annealing furnaces, and test stands needed for development of long-range solid-propellant missiles were repaired, modified, or created.

- ***Had the effort continued, a long-range solid-propellant missile could have been produced within 5 years, according to one senior Iraqi missile developer.***

- According to an engineer in the Iraqi missile program, in early 2001 per directive of Huwaysh, a study was undertaken by the Al Fida' General Company to design a solid-propellant missile launcher for a missile with a range of 500 km. Work on this project ceased upon the arrival of UNMOVIC inspectors. Documentation of this project was destroyed with the exception of engineering designs for the launcher shown in Figure 20.

New Cruise Missile Projects

After UNSCOM inspectors left in 1998, Iraq continued with one cruise missile project and began another. Both of these modifications were to the HY-2 anti-ship cruise missile. The first project, which was declared by Iraq in its July 1996 Full, Final, and Complete Disclosure (FFCD) as the Al Faw 150/200, was an attempt to extend the range of the HY-2 from about 100 km to 150 km. An attempt to build a 1,000-km range, turbojet-powered cruise missile was a more ambitious second project known as Jinin that began in late 2001.

HY-2 Range Extension

'Abd-al-Tawab 'Abdallah Al Mullah Huwaysh, the Minister of Military Industrialization, created the Special Projects Office (SPO)—directly subordinate to himself and with direct links to the President's Office—because he wanted a few key projects to receive high-level attention and financial support. One such secret project (between MIC, the Iraqi Navy, and the Al Karamah General Company) sought to extend the range of the HY-2 cruise missile to 150 km using cannibalized components from their inventory of surplus C601 and C611 anti-ship cruise missiles and changes to the propulsion system.

- According to an Iraqi scientist, the first test was conducted in August 1999 at a location in Basrah. Though this land attack cruise missile (LACM) test was declared by Iraq to the UN in the Currently Accurate, Full, and Complete Declaration (CAFCD), Iraq did not disclose that this was part of a range extension project.

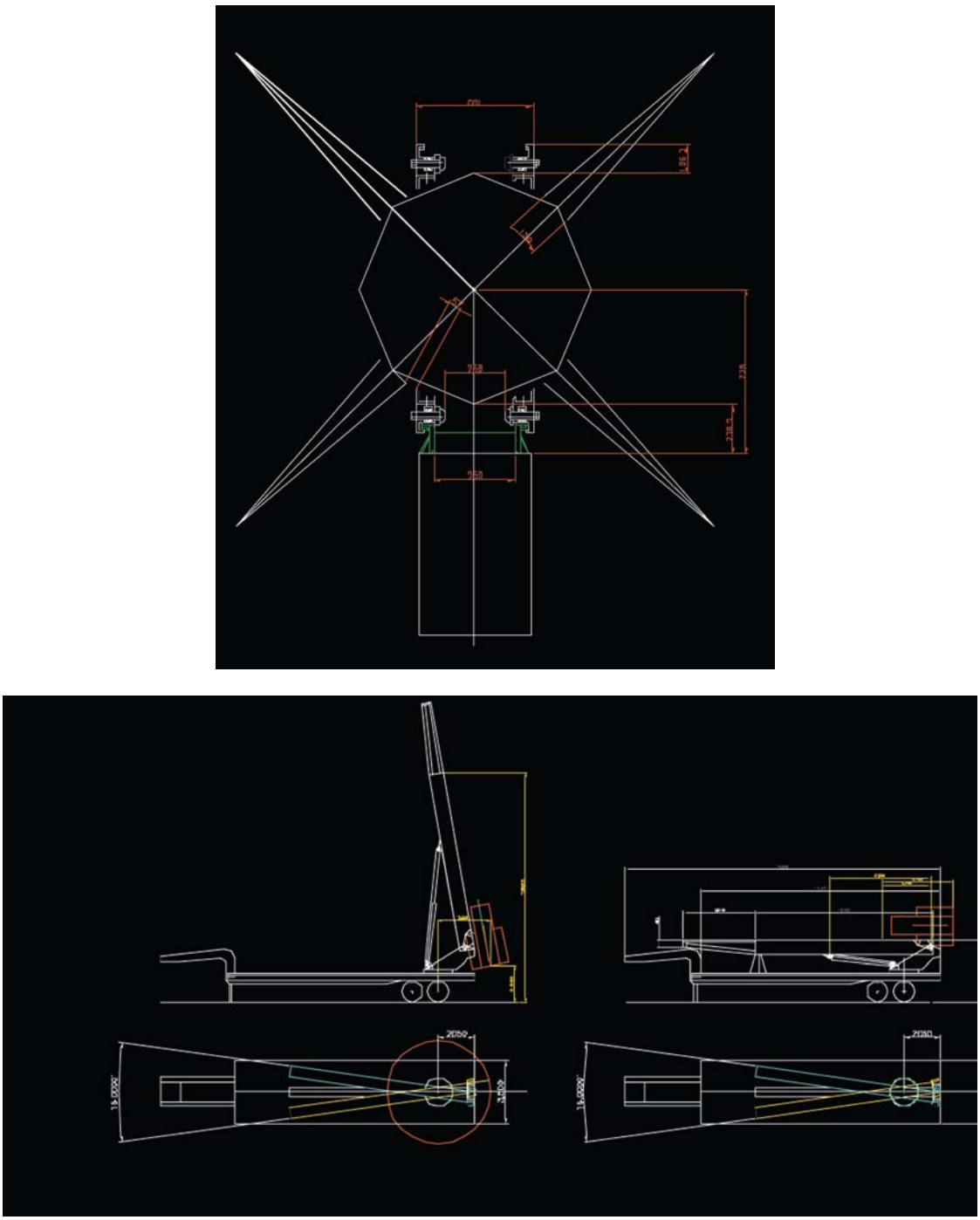

Figure 20. *Designs for long-range solid-propellant missile launcher.*

Propulsion System
According to source reports, Al Karamah experimented with different engines and propellant modifications to increase the HY-2 range. A different engine (C-611) using higher-energy propellants would be required to reach the range goal for the project.

- Conflicting reports from engineers involved in the program indicate Iraq used engines from the P-15, C601, and C611 as replacements for the HY-2 engine, and that each attempt was successful.

- According to several missile officials, Al Karamah changed the fuel used in the HY-2 from TG-02 to higher-energy AZ-11 (a blend of 89% DETA and 11% UDMH). The change required adjustments to the engine fuel pumps to optimize the fuel/oxidizer mixture ratios.

- A flight test of the modified HY-2 achieved a range of 168 km, according to Huwaysh. After that, Al Karamah made engine and tank adjustments to keep the range below 150 km to avoid the attention of the UN.

- ***ISG judges it unlikely that all three engine replacements were successful. Changing the fuel and readjusting all of the engines mentioned would probably not result in a range extension to 168 km.*** A range extension to 150 km is more likely achievable by using the C-611 engine with AZ-11 fuel.

Warhead
Several sources have indicated the intended warhead for the extended-range HY-2 was a HE warhead consisting of 500 kg of TNT. ***ISG has uncovered no information to suggest this cruise missile would carry a submunition or CBW warhead.***

Guidance and Control
Iraq's extended-range HY-2 program would depend upon the acquisition of navigation and guidance systems that were more sophisticated than the original or readily available components; acquisition of such systems were forbidden by UN sanctions. Iraq began making plans to acquire such systems, but this was not a priority for the program.

- An engineer in the program indicated that modification and testing of the propulsion system were the first priorities, and navigation and guidance would be addressed nearer the end of the program development cycle.

- In the event Iraq could not scavenge or adapt guidance systems from other missiles like the C-611, it planned to acquire them from outside sources.

Conclusions
Reporting from several sources consistently indicates that the extended range HY-2 successfully flew to at least 150 km, and possibly 168 km. Although the goal of the program was to provide a greater stand-off capability against ships and to make up for the loss of an air-launched cruise missile capability, the research directly contributed to the longer range Jinin project.

- If the extended-range HY-2 program did not exceed 150 km during flight tests it likely would not have constituted a violation of UN resolutions.

- Huwaysh commented that Iraq targeted Kuwait with its deployed extended-range HY-2 missiles during OIF**.**

The Jinin [Jenin] Project

In 2001 and 2002, Iraq attempted to convert the HY-2 anti-ship cruise missile into a 1,000-km-range land-attack cruise missile (LACM), which would build on the HY-2 range extension project that had already introduced upgrades—performed by the Al Karamah General Company —to the flight computers, engines, and propellants. ***A missile with this range would be able to reach targets in Iran and Israel from within Iraq's borders.*** The Jinin project was interrupted by OIF before any flight tests occurred.

- According to an engineer in the Iraqi missile program, the Jinin project was conceived in November 2001 and received MIC approval in June 2002. In this time frame a host of other long-range projects involving ballistic missile systems were receiving

increased attention. The project officially started on 1 June 2002 and was intended to be a three-to-five-year development project, but it was reportedly canceled in December 2002 after UNMOVIC entered Iraq. However, the original airframes and rocket engines were reassembled and returned to storage about two weeks after UNMOVIC's arrival for fear of the project being discovered.

- The Al Karamah General Company was assigned overall project responsibility with the DG of Al Karamah (Dr. Muzhir), ultimately responsible for the project. However, Brigadier General Nadhim from Al Karamah was considered to be the project manager and systems engineer.

The initial concept involved modifying an HY-2 by replacing the sustainer propulsion system with a modified helicopter turboshaft engine to sustain cruise flight, which would eliminate the oxidizer tanks and enable a much longer range. The program fell into four distinct phases, according a senior program manager, who felt a flight test could be conducted in three years.

- Phase one would use computer simulations to test concepts for maintaining structural integrity and stability during engine integration and would attempt to convert surplus helicopter turboshaft engines to produce thrust rather than torque.

- Phase two would test and install the engines.

- Phase three would build and flight test a prototype.

- Phase four would work on guidance, navigation, and control.

The Jinin program involved several research, development, and production organizations: Al Quds for airframes and warheads, Al Milad for G&C systems and aerodynamics, Al Fida' for the launcher, Ibn-Firnas and Iraqi army helicopter workshops for the engine modifications, and Al Karamah for final assembly.

Propulsion System

Iraq planned to convert the HY-2 from rocket-powered to turbojet-powered using surplus helicopter engines. Initially, Iraq planned to use Mi-8 "TV-2" helicopter turbines modified to produce thrust rather than torque.

- Propulsion engineers at Ibn-Firnas estimated that the Jinin would require 2,670-Newtons (600 pounds) of thrust, but the TV-2 engine testbed (captured by ISG) was capable of producing only 2,000-Newtons (450 pounds) of thrust. As a result, Ibn-Firnas began studying the conversion of the Mi-17 "TV-3" helicopter engine.

- UNMOVIC inspections commenced before TV-3 testbed demonstrations could be completed, and the testbed was shut down to prevent inadvertent observation by inspectors.

- Both of these engines could fit into the HY-2 airframe without extensive modifications, thus avoiding new aerodynamic problems caused by structural changes. The engine air intake would be located on the bottom of the missile about midway along the body.

Reportedly, Ibn-Firnas engineers believed the modification from turboshaft to turbojet would be difficult because the stators (vanes) could not be removed since they were integral to the engine's ball bearing assembly. They believed that, although the modifications would be challenging, they could solve the problems with enough time and money. However, reports vary as to the success and extent of the overall engine modification program, and to the status of the design documentation.

- According to a source with excellent access, engineers only reached the modeling phase of development with no tests of an operating engine for Jinin. Additionally, all of the engine modeling work, drawings, and related documents were destroyed at Ibn-Firnas by fire and looting after OIF.

- **An engineer with direct access indicated that the design work was intentionally destroyed in February 2003 due to fear of UNMOVIC's possible discovery of the project.** The source believed it could be regenerated within a couple of weeks if UNMOVIC left and the leadership demanded the project continue. This concept is supported by reports of Saddam's goal for a program reconstitution capability of less than six months.

- An engineer in the Iraqi missile program stated that a modified Mi-8 engine test succeeded, but with lower than expected thrust levels. These lower thrust levels were attributed to the poor condition of the older engine. Iraq expected that using newer Mi-17 engines would alleviate the thrust problem, but that work was interrupted by the arrival of UNMOVIC before testing could begin.

- The same source indicated that the modified Mi-8 engine was moved to Ibn-Firnas for storage. An Mi-8 turboshaft was recovered from the engine static test stand at Ibn-Firnas by US officials in late June 2003. Multiple sources involved in the program indicate the engine was used in the Jinin program. A small diffuser, found in the Ibn-Firnas junk yard and identified by the same source to be from the Mi-8 engine in coalition possession, was mated successfully with the engine exhaust port, adding some credibility to the source's claim.

Warhead

The Jinin missile was intended to carry a HE warhead consisting of 500 kg of TNT. ***ISG has uncovered no information to suggest this missile would carry submunitions or CBW warheads.***

Guidance and Control

According to a senior program official in July 2003, the Jinin navigational accuracy would not be an important factor in the first phases of the project. The priority was simply to get a missile to fly 1,000 km with an HE warhead. This approach was not unusual for Iraq—the Al Husayn project had adopted the same attitude, which is why the Al Husayn was so inaccurate, according to the senior program official.

- The program official was initially convinced that the guidance system for the HY-2 could be used for the Jinin project. He also stated that the project had not progressed to the stage of working on the guidance section. The project researchers first wanted to verify the engine would work and could be mounted successfully on the HY-2 airframe. Had these steps been successful, they would have begun work on the guidance and other sections.

- The HY-2's existing guidance system was not accurate enough and Iraq did not have access to any guidance system that would be sufficiently accurate. The program official indicated that the HY-2 guidance system would eventually be replaced by a GPS acquired from abroad. As an interim solution, Al Milad considered using the guidance system from the R-40 (AA-6) missile, which uses three accelerometers and three gyroscopes. ***Clearly, Iraq again assumed that sanctions were not an inhibiting factor.***

- Another issue, acknowledged by the program official, involved the control and stability of the missile given the internal rearrangement of the sub-system components necessary to accommodate the modified engine (and potential additional fuel tank).

Conclusions

The Jinin project was in the early R&D phase when it was interrupted by the return of UN inspectors, and it was subsequently canceled. Although its inherent payload capability of 500 kg could have been adapted for WMD, there is no evidence of intent for WMD delivery. If the project had continued, it most likely would have violated UN resolutions.

Unmanned Aerial Vehicles (UAVs) and Remotely Piloted Vehicles (RPVs)

ISG has uncovered only limited information indicating an overall program intent for unmanned aerial vehicles (UAVs) to deliver chemical or biological warfare agents. In addition, ISG has noted that Iraq appears to have embarked on a number of loosely related UAV efforts since 1990. These efforts can be grouped into two major categories: efforts to convert manned aircraft into remotely piloted vehicles (RPVs), and efforts to design and build indigenous UAVs, as depicted in Figure 21. Conversion programs include the MiG-21 and L-29 RPVs, and indigenous developments include the Ibn-Firnas and Al Quds small UAV programs.

Brief History
Iraq's UAV efforts began in the late 1980s with the development of small RPVs for surveillance and reconnaissance roles and continued in 1990 with the attempt to convert a MiG-21 fighter aircraft into an RPV. The Iraqis admitted to the UN that the intent for this program was to develop a CBW delivery platform. After the MiG-21 RPV program failed in 1991, Iraq started the Yamamah program to research small indigenous UAVs. In 1994-95, the Iraqis resumed efforts to convert a manned aircraft into an RPV, this time with the Czech L-29 trainer aircraft.

- Reports differ on the purpose for the L-29. Some Iraqi officials report hearsay and suspicion that the system was being developed for CBW delivery. Other sources report the L-29 RPV program had more benign missions such as target drone and reconnaissance.

- There is no definitive link between the L-29 and WMD. Ultimately, the L-29 RPV was a technical failure and had its funding terminated in 2001.

In the 1999-2000 timeframe, Minister of Military Industrialization Huwaysh felt that small, cheap UAVs were better than converted manned aircraft, so Iraq began an indigenous reconnaissance UAV and target drone development program in the Ibn-Firnas General Company that built on the Yamamah research program of the early 1990s.

- Ibn-Firnas successfully developed the Al Musayara-20 UAV as a battlefield reconnaissance UAV, which was sold to the Iraqi Army and Republican Guard in 2002.

- A second development program called Al Quds began at the instigation of former Yamamah Program Director Brigadier Engineer Dr. 'Imad 'Abd-al-Latif Al Rida'. MIC directed that this program focus on larger UAVs to meet military requirements for airborne electronic warfare programs. The Al Quds program had not yet succeeded by the onset of OIF in 2003.

Evidence available to ISG concerning the UAV programs active at the onset of OIF indicates these systems were intended for reconnaissance and electronic warfare. However, this evidence does not rule out the future possibility of adapting these UAVs for CBW delivery if the Iraqi Regime had made a strategic decision to do so.

- ***While the Al Musayara-20 UAV and, if fully developed, the Al Quds UAVs had the capabilities required—range, payload, and programmable autonomous guidance—to be used as CBW delivery systems, ISG has not found evidence the Iraqis intended to use them for this purpose.***

- ***ISG has obtained indirect evidence that the L-29 RPV may have been intended for CBW delivery, but this program ended in 2001.***

MiG-21 RPV

Background
In November 1990, MIC and the Iraqi Air Force Command embarked on a program to modify the MiG-21 fighter into an RPV for use in one-way "suicide" missions. The operational concept was for the aircraft to take off under remote control, presumably by a ground station, then after reaching a certain altitude control would be transferred to another, piloted aircraft in the area. The piloted aircraft would then remotely fly the MiG-21 RPV to the target area whereupon control would be transferred to the RPV's autopilot for the terminal phase of the mission.

- The Iraqis equipped the MiG-21 with an autopilot from the MiG-23 fighter, due to that autopilot's better capability to ensure stable flight and to support all the necessary electrical and mechanical systems. The MiG-21 RPV was also fitted with servo-actuators for the control surfaces, throttle, and brakes. The remote-control system used was a German system produced by the Groupner Company, with eight channels, and operated on a frequency of 27 MHz.

- At least one flight test was conducted on 10 January 1991 at Al Rashid Air Base, Baghdad, but technical problems required the onboard pilot to take control of the aircraft to insure safe recovery and landing.

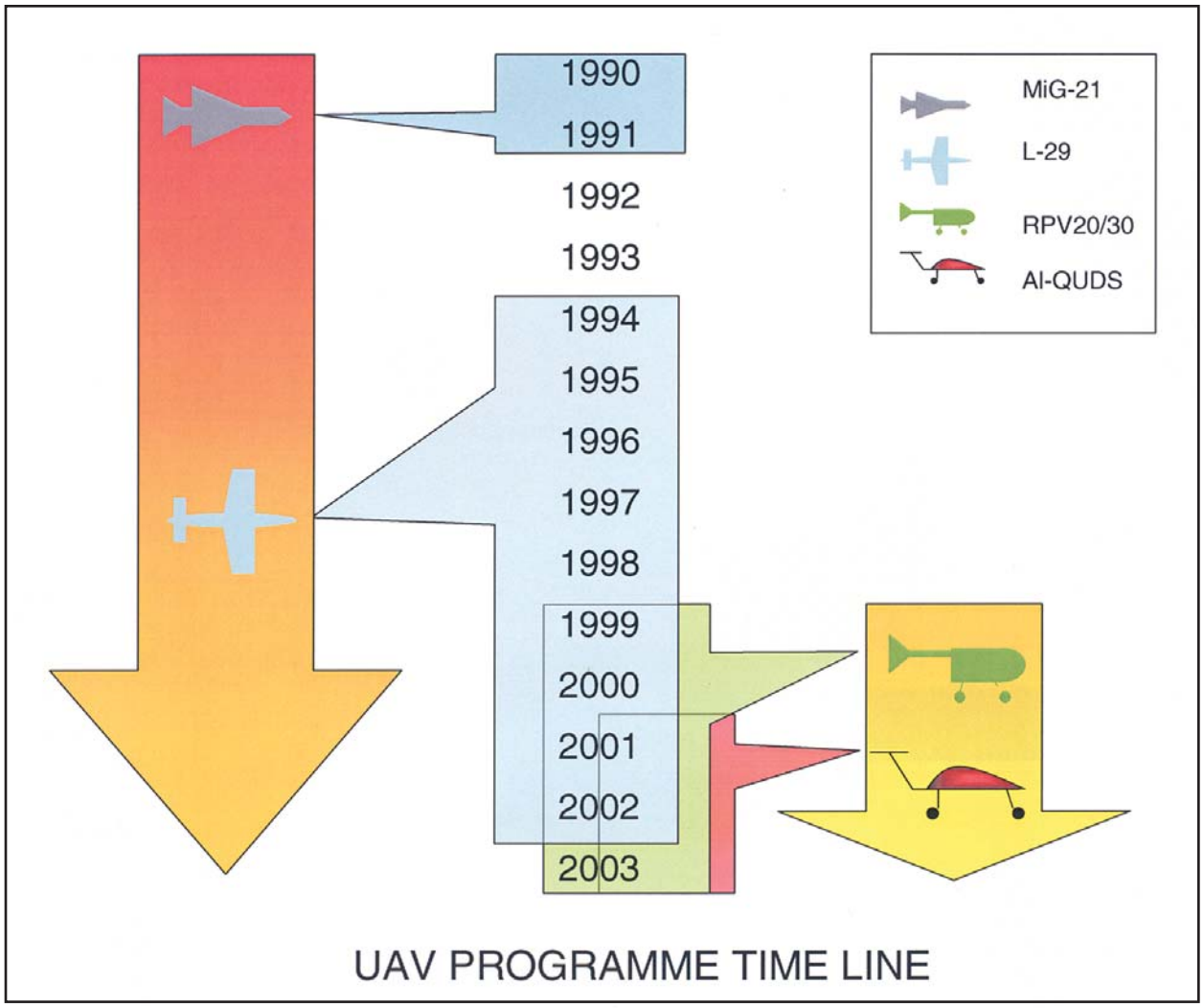

Figure 21. *Iraqi UAV programs.*

Roles and Missions
Before OIF, Iraq's National Monitoring Directorate (NMD) conducted an investigation into the MiG-21 RPV program to prepare a response to UNMOVIC. The NMD concluded that the MiG-21 RPV program failed due to lack of time and expertise to develop a workable control system. They also concluded that the MiG-21 RPV had been intended for a chemical and/or biological weapons delivery role.

- In the mid-1990s, Iraq declared to the United Nations that the MiG-21 RPV had been intended for a CBW role.

- The simple onboard sprayer system tested by Iraq (see the Weaponization section in the BW and CW chapters) would have been operated by a timer that would be set before takeoff. This RPV was intended for a one-way flight, flying until its fuel was exhausted.

- The program appears to have ended sometime in 1991. The NMD reported that the absence of documentation of this fact and other program details was caused by bombardment of the work site (presumably during Desert Storm), which was a "shed" in the aircraft repair factory at Al Rashid Air Base, Baghdad.

L-29 RPV (Al Bay'ah)

Background
Following the failure of the MiG-21 RPV program in 1991, Iraq's Military Research and Development Center (MRDC) in 1995 began a program call Al Bay'ah to modify the Czech L-29 trainer aircraft into an RPV. According to a report, in 1997, MRDC's Drone Directorate became the Ibn-Firnas Center and continued with the development of the L-29.

- Ibn-Firnas modified the L-29 with a remote-control system using four cameras (primary and secondary forward view; primary and secondary cockpit view) feeding two displays at stations in a control van adapted from the control system of the Italian Mirach-100 UAV. Initial taxi tests of the L-29 RPV took place at Al Rashid Airfield in Baghdad, but due to an accident (the aircraft impacted the runway barriers), Ibn-Firnas moved the program to Al Mutasim Airfield (also known as Samarra East Airfield).

- The first flight test occurred on or about 13 April 1997 and was successful, followed by a second successful test in June 1997. These tests remained in the airfield traffic pattern.

- The third flight test was intended to test the maximum range of the video and command signals. The aircraft successfully flew 60-70 km southeast of Al Mutasim, but then the ground station lost the video signal from the aircraft and it crashed. Following this, Ibn-Firnas attempted to improve the aircraft's controllability by installing the auto stabilizer system from the Chinese C-611 anti-ship cruise missile. This modification was largely unsuccessful due to excessive instrument drift.

Although bombing of Al Mutasim in 1998 during Desert Fox delayed progress on the L-29 RPV, Ibn-Firnas conducted approximately 26 more flight tests between 1999 and 2001. All these tests had a pilot in the cockpit and focused on improving the control system.

- A single source stated that in the spring of 2001, Ibn-Firnas attempted an unmanned flight that resulted in a crash. Following this crash, Ibn-Firnas recommended canceling the program. Huwaysh agreed and terminated funding for the program.

- The initial program manager for the L-29 RPV program was Dr. Mahmud Modhaffer. Dr. Mahmud departed the program in 1996 and was briefly replaced by Dr. 'Imad until 1997. Dr. 'Imad was subsequently replaced by MIC Deputy Director Muzahim Sa'b Hasan Muhammad Al Nasiri, who, according to a worker on the program, had very little technical competence.

Roles and Missions
Multiple sources have described different roles and missions for the L-29 RPV. These include acting as a decoy for coalition aircraft, an air defense target,

reconnaissance, and potentially a CBW delivery platform. ***ISG has not been able to confirm or deny that the L-29 had an intended CBW delivery role.***

- Former officials of Ibn-Firnas reported that the aircraft was to be used as a decoy for coalition aircraft enforcing the no-fly zones. It would lure them into an ambush using SAMs (colloquially referred to as a "SAMbush"), although this mission was never flown. Ibn-Firnas personnel also reported that the aircraft was to be used as a target drone for the Air Defense Forces.

- A management level official reported that the aircraft would be used for reconnaissance and possibly electronic warfare. He also described the intended use of the aircraft in November 1997 as a "SAMbush" decoy.

- An Iraqi aircraft engineer, with indirect access to the information, reported that in 1995, many Iraqi Air Force engineers believed the intended use of the L-29 RPV was to attack a US aircraft carrier with chemical or biological weapons. This source claims to have been informed by colleagues who worked on the L-29 RPV that the aircraft would be outfitted with biological weapons to attack a US carrier in the Persian Gulf, but the source had no information on how that attack would be conducted. In addition to the indirect information about biological weapons, the source also speculated that the L-29 RPV could be armed with chemical weapons.

Huwaysh's Accounting of the L-29 RPV Program

Huwaysh asked for a review of the L-29 RPV program shortly after taking over as MIC director in 1997; presumably as part of a broader review of all MIC programs. Huwaysh said that he was briefed that the roles of the L-29 RPV were first as a battlefield reconnaissance system and second as a lure for US aircraft. As a mechanical engineer, Huwaysh believed the program was foolish for a number of reasons.

- First, turning a manned aircraft with a 500-km range into an RPV with a UN-mandated maximum range of 150 km was an inefficient use of the aircraft.

- Furthermore, at the time of the briefing, Ibn-Firnas had not been able to extend the range of the aircraft beyond 70 km due to line-of-sight limitations with the ground control station. This short range would limit the RPV's utility as a reconnaissance system.

- Finally, Huwaysh felt that there were too few L-29 aircraft available for conversion and that they were too expensive to operate for the stated mission, believing that smaller, cheaper UAVs were a better option.

Even with these concerns, Huwaysh was unable to immediately cancel the L-29 RPV because of Saddam's personal interest in the program. However, after several crashes, combined with the Air Force's refusal to provide more L-29s for conversion, Huwaysh convened a critical review of the program in late 2000 with the Ministry of Defense. At this review, the Ibn-Firnas DG Dr. Ibrahim Hasan Isma'il Smain provided a negative evaluation; following a crash in the spring of 2001, Huwaysh terminated funding for the program.

During custodial interviews, Huwaysh expressed skepticism of the stated mission (reconnaissance/ decoy) of the L-29 RPV. He reported that he inherited both the program and its program manager when he became MIC Director in 1997. In his engineer's judgment, Huwaysh considered the L-29 RPV unsuited to the battlefield reconnaissance role.

- According to Huwaysh, Iraqi officials never tested reconnaissance cameras on the L-29. Further, while the Air Force was the most likely customer for such an aircraft, it was not involved in the RPV development and did not appear to be interested in the program.

- ***In November 2003, Huwaysh stated that the L-29 was a "100 percent replacement for the MiG-21" RPV and was intended to fulfill the same mission as the MiG-21. When told that Iraq had declared the MiG-21 RPV was intended to be a CBW delivery platform, Huwaysh responded, "Whatever knowledge you have of the MiG-21 is directly related to the L-29."***

- Huwaysh also stated that Iraq developed the MiG-21 RPV as a CBW delivery platform for use against Iran and that a sprayer for the aircraft had been developed. In his opinion, the L-29 was more suitable for CBW dissemination than the MiG-21.

- Repeated attempts (November 2003, December 2003, and April 2004) to get Huwaysh to be more explicit on this point have been unsuccessful. ***In more recent interviews, Huwaysh asserted that he had no direct knowledge of a CBW delivery role for the L-29 RPP;*** he only suspected that that might be the intent because of its unsuitability for its stated reconnaissance mission and the publicity about the West's suspicions about Iraq's WMD programs.

When confronted by the interviewer that the Minister of Military Industrialization must know such details, Huwaysh was adamant that, in Saddam's Iraq, compartmentalization between organizations prevented full knowledge by anyone but the closest members of Saddam's inner circle ("black circle," in Huwaysh's words). Huwaysh denied being a member of that inner circle and denied being a political or strategic decisionmaker.

Conclusions

ISG cannot confirm or deny an intended WMD delivery role for the L-29 RPV. The target drone mission for the L-29 RPV, as described by a former Iraqi Air Force officer who worked on the program from 1997-2002, is consistent with Western practice for AAM and SAM live fire training. Further, Huwaysh reported that the number-one lesson Iraq learned from Desert Storm was the need to significantly improve air defenses; a target drone of this type could be used to test new air defense systems and to train crews. However, Huwaysh did not associate the L-29 RPV with this mission. Finally, the size, operating cost, and complexity of the L-29 exceed the requirements for a battlefield reconnaissance platform.

- If the L-29 RPV mission was truly innocuous, ISG judges that Iraqis from the shop floor up to the MIC director would know that. Also, the small number of L-29s available for conversion would minimize its utility for missile live fire testing and training.

The inconsistency in reporting on intended roles for the L-29 RPV, from individuals who should be in a position to know, is troubling. Huwaysh's CBW delivery "suspicions" may be hints of actual knowledge that he is unwilling or afraid to share with interviewers. This, combined with indirect reporting of a WMD delivery role from another source, prevents us from eliminating an intended WMD delivery role for the L-29 RPV.

- The aircraft's payload capability and flight performance are sufficient for use as either a chemical or biological weapons platform.

- Iraq had previously experimented with modifying Mirage F1 external fuel tanks into biological weapons dispensers and had used L-29 drop tanks to produce an agricultural spray system for the Hughes 500 helicopter.

- Iraq had the capability to develop chemical or biological weapon spray systems for the L-29, but there is no evidence of any work along these lines.

ISG judges that, even though this program did not come to fruition, a foundation of knowledge and a technical basis was obtained from which Iraq could resurrect chemical or biological weapon dispensing system programs.

Al Yamamah Project

Background

In the 1990s, Iraq began research and development work on UAVs designed and built specifically as unmanned vehicles. The initial work was the responsibility of Iraq's Military Research and Development Committee (MRDC), directed by Dr. 'Imad from 1993 until 1996. Between 1995 and 1997 the MRDC worked on the Al Yamamah UAV project, which formed the foundation of subsequent indigenous UAV development in Iraq. The Al Yamamah project consisted of three designs, the Al Yamamah 2, Al Yamamah 3, and Al Yamamah 4.

- The Al Yamamah 2 and 4 UAVs were propeller-driven with pusher piston engines.

- The Al Yamamah 3 was jet powered, using a TS-21 turbo-starter from the Russian Su-7/FITTER aircraft.

Iraqi engineers realized that most UAVs were not jet powered because slower, propeller-driven UAVs were simpler to construct and control and could remain airborne longer. Subsequently, the Ibn-Firnas General Company copied the Yamamah 2 design, increased the size of its tail boom, and renamed it the Al Musayara-20 (aka RPV-20 or UAV-20).

Ibn-Firnas UAVs

Background

Orders by Saddam for a competition between Ibn-Firnas and the Iraqi Air Force to produce the first fully autonomous UAV, combined with problems with the L-29 RPV, prompted Ibn-Firnas to concentrate on smaller UAVs. Saddam directed that funding increases slated to expand and improve the Air Force be transferred to building UAVs because Iraq was unable to acquire new fighter and bomber aircraft.

Ibn-Firnas, headed by Major General Ibrahim Isma'il Smain, had at least three UAV projects under way. The first was a small RPV known as Sarab-1 used solely as an air defense artillery training target. The Sarab-1 had a 1-to 1 ½-km range and some 60-70 were built. The second was the Al Musayara-20, which was larger, powered by a 342-cubic centimeter (cc) motor, and used commercial GPS navigation to fly a programmable flightpath (see Figure 22). The third was colloquially known as the "30-kilo airplane" because it was intended to have a 30-kg payload capacity.

- Prototypes were built and tested, but the "30-kilo" program experienced controllability problems and was not completed by the time of OIF. The "30-kilo airplane" may also be known as the Al Musayara-30 or RPV-30 (see Figure 23).

In June 2002, an Al Musayara-20 UAV flew a demonstration flight that lasted three hours and covered a total distance of 500 km, although a source with direct access claimed the UAV remained within 15 km of its launch point. The UAV was initially controlled by the ground control station, then switched to autopilot shortly after takeoff and remained on autopilot until recovery.

- In addition, this successful flight renewed the military's interest in the Al Quds UAV project, which was concurrently developing larger UAVs with greater payload capacity for other missions like communications and radar jamming.

In the fall of 2002, MIC selected the Al Musayara-20 over the Iraqi Air Force entry (called the Iraqi Hawk) due to its superior performance. In November 2002, Ibn-Firnas concluded a contract to provide 36 Al Musayara-20 UAVs to the Iraqi Army for battlefield reconnaissance (the Republican Guard ordered a similar number). The contract specified the delivery of:

- Thirty (30) Al Musayara-20 with autonomous, programmed guidance;
- Six (6) Al Musayara-20 with remote-control capability, for training purposes only;
- Twelve (12) Yamama-11 training aircraft (probably targets);
- Eight (8) simulators;
- Control, navigation, and reconnaissance equipment;
- Six (6) ground control stations.

ISG has been unable to confirm if the specified items were delivered.

Characteristics

Requirements for the Al Musayara-20 in the Army contract include "…aircraft equipped with control, remote control and navigation systems via GPS, and gyroscopic autopilot system" (i.e., automatic preprogrammed G&C using GPS and gyros). Further specifications are shown in Table 5.

The Al Musayara-20 used a video camera for reconnaissance, but had no means of downlinking the video in real time. The video was recorded on board and could be viewed only after the aircraft was recovered. At one point, there was a request for Ibn-Firnas to develop an electronic countermeasures payload for this aircraft, but it lacked sufficient payload capacity, according to a UAV engineer.

Missions

Ibn-Firnas developed the Musayara UAV as a reconnaissance platform, according to Huwaysh, driven by lessons learned from the Iran-Iraq war where many general officers were shot down on helicopter reconnaissance missions. However, other roles were considered. In late 2002 or early 2003, Republican Guard Major Anmar 'Amil Hiza' obtained approval from the Presidential Diwan to use UAVs like cruise missiles to attack command and control targets of known locations. Anmar contacted Ibn-Firnas and requested a flight test be arranged to determine if existing UAVs could perform this mission. Anmar's requirement was for airplanes that work as cruise missiles, covering the distance of 120 km, carrying 20 kg of explosives ("TNT") and flying over 3 km high, with the accuracy of 99% after entering the coordinates of the target into the flight computer.

- In mid-January 2003, Ibn-Firnas performed the requested flight test at Tamuz Air Force Base southwest of Baghdad using an Al Musayara-20 UAV with a pre-programmed flightpath launched from the back of a truck.

- Shortly after takeoff, the UAV was switched from manual control to autopilot and flew the pre-programmed route to Muhammadi AFB, a distance of approximately 80 km.

- Anmar originally wanted the UAV to crash at a specific geographic location to prove that it could hit a planned target, but Ibn-Firnas engineers resisted this plan, insisting on recovering the UAV by parachute so it could be used again.

Reportedly, Anmar was impressed by the test and ordered Ibn-Firnas to build him 50 Al Musayara-20 UAVs. Ibn-Firnas officials, however, were suspicious of Anmar's story about using TNT and, to avoid committing to the project, advised Anmar' they would need more details on the mission in order to build the UAVs for him. Anmar reportedly became very nervous at being questioned by Ibn-Firnas officials and demanded they carry out the order, but Ibn-Firnas refused.

- Anmar returned later to MIC with a letter from 'Abd Hamid Mahmud Al Khatab Al Nasiri, Saddam Husayn's personal secretary, ordering Huwaysh to form a committee to investigate why the first order was not carried out and who was resisting implementing it.

- Huwaysh appointed his deputy, Muzahim Sa'b Hasan Muhammad Al Nasiri, as head of the committee, which determined that Ibn-Firnas' refusal was justified on technical grounds.

- Huwaysh also expressed skepticism at the concept of loading the UAVs with 20 kg of TNT, believing that missiles could do the job more effectively. He feared that, with all the publicity over possible Iraqi possession of chemical and biological weapons, Anmar may have had something more deadly in mind.

Despite the committee's decision, Ibn-Firnas built six Al Musayara-20 UAVs (one prototype and five production models) but never delivered them to Anmar. The UAVs were built at a new UAV site near the Al Karamah General Company facility in the Waziriya district of Baghdad. These UAVs were not equipped with cameras or recovery parachutes.

- Completion of these UAVs was delayed due to unspecified problems with the autopilot.

- After OIF, two Al Musayara-20 UAVs were recovered from the Waziriya site, probably two of the UAVs manufactured in response to Anmar's requirement.

Foreign Assistance

Although the Ibn-Firnas UAVs were indigenous Iraqi designs, they were enabled by and dependent on foreign-procured components. These programs would not have been possible given strict adherence to sanctions and thus it was implicit that obtaining foreign material was not a problem. Examination of two Al Musayara-20 UAVs captured after OIF shows they used British WAE-342 piston engines.

- Information provided by Huwaysh and other intelligence indicates that a Ukrainian company known as Orliss, headed by Dr. Olga Vladimirovna, provided some of the engines for the UAVs.

- The Iraq based Rabban Safina Company also tried to acquire WAE-342 engines through Australia, along with gyroscopes and servomechanisms from multiple suppliers.

In addition to the engines, Ibn-Firnas imported Micropilot MP2000 and 3200VG autopilots, embedded GPS cards, and industrial computers for the Al

Figure 22. *Ibn Firnas Al Musayara-20.*

Figure 23. *Ibn Firnas Al Musayara-30.*

Table 5	
Length	3.45 m
Wingspan	4.80 m
Height	0.95 m
Gross Weight	116 kg
Empty Weight	80 kg
Maximum Takeoff Weight	115 kg
Maximum Speed	170 kph
Maximum Flying Time per Tank	3 hrs
Maximum Altitude	3,000 m
Table 5 Al Musayara-20 specifications	

Musayara-20 from Advantech, a Taiwanese firm. Engineers at Ibn-Firnas wrote the guidance software for the Advantech computers incorporated in the guidance system. GPS waypoint data were programmed on a laptop computer and loaded into the UAV's guidance computer prior to flight.

- According to a former high-level Iraqi official, the Iraqi ambassador to Russia, 'Abbas Khalaf Kunfadh, was directly involved in purchasing GPS components for Iraqi UAVs. He bought GPS equipment from Russian technicians who were employed by the Russian government, but who designed and sold the GPS devices out of their homes to make extra money. 'Abbas reportedly acquired the GPS devices without the knowledge of the Russian government.

- According to a high-level official in the Iraqi UAV program, Iraq obtained four MP2000 and two 3200VG autopilots through an Australia-based procurement agent. These autopilots were never installed in UAVs because they arrived just before OIF. Iraqi officials deny attempting to intentionally acquire mapping software of the United States but did receive mapping software that came as part of the package with the MP2000 and 3200VG autopilots. The source indicated that these items were located at Ibn-Firnas prior to OIF but was unaware of their current location.

Potential UAV Control Upgrade

In 1998, the Al Razi General Company of MIC began experimental work on a laser control system for use with UAVs. The experiments culminated with a UAV test flight using the laser control system in early 2000 at the Tikrit Air Academy. The UAV, identified as an Ibn-Firnas "Musayara," flew to a distance of 6-10 km at an altitude of 700 meters.

- *The Musayara UAV in this experiment was painted red with a yellow stripe as was the vehicle identified by an Ibn-Firnas UAV technician as the "30 kilo" aircraft. However, the dimensions provided for the UAV used in the laser guidance experiment are smaller than the Al Musayara-20.*

- *The laser control system served only as an uplink command signal, although research was under way on a two-way control link. The laser control system required an optical tracker to track the UAV and keep the laser aimed at the laser receiver on the UAV.*

In March 2000, Al Razi Company published a report on the laser control flight test for MIC. Huwaysh was displeased with the results. He felt the system was not practical for UAV control because of the short range of the system, and he canceled the program.

Other foreign components identified in the Al Musayara-20 (depicted in Figure 24) include:

- Remote-control unit labeled "PCM Telecommand System, Skyleader Radio Control Limited;"
- Feranti Technologies vertical gyro Type FS60P;
- Video recorder labeled "VCR Vinton Military Sytems Ltd;"
- Single rate gyro units labeled "BAE Systems;"
- Electronic unit labeled "DMS Technologies, 08/02;"
- Sony 700X Super Steady Shot, digital eight video camera, model DCR-TRV530E;
- Humphrey vertical gyro, model VG34-0803-1;
- Multiplex Micro-IPD 7-channel narrowband receiver 35 MHz;
- Schmalband-Empfanger multiplex Uni 9, 35 MHz.

Conclusions

The Ibn-Firnas programs were Iraq's most successful unmanned aerial vehicle programs. Although heavily dependent on foreign procurement, Ibn-Firnas successfully developed the Al Musayara-20 UAV, capable of long-range, pre-programmed autonomous flight and intended to perform battlefield reconnaissance for the Iraqi Army and Republican Guard.

- Less successful were attempts to develop a larger UAV with a greater (30 kg) payload. ***However, given time and the successful track record established by the Al Musayara-20, ISG judges Ibn-Firnas would most likely have succeeded in developing larger, more capable UAVs.***

The June 2002 demonstration flight and the technical specifications in the Army purchase contract clearly reveal that the Al Musayara-20 may have violated the range restrictions imposed by United Nations Security Council Resolutions. Engineering analysis indicates the Al Musayara-20 was capable of a one-way fuel-exhaustion range well in excess of the 500 km flown in June 2002, and with the programmable GPS-based autopilot, the Al Musayara-20 was not "tethered" by a remote-control system.

- It was necessary for the Al Musayara-20 UAV, in its reconnaissance role, to be able to remain aloft over the battlefield for extended periods and image a large number of targets per sortie. These performance parameters were not necessarily indicative of intent to use the Al Musayara-20 as a chemical or biological warfare delivery platform but provide a limited inherent capability.

Al Razi General Company's 1998-2000 attempts to develop a laser, vice radio, control system would, if successful, have allowed Iraq to launch and recover UAVs without transmitting in the radio frequency spectrum. The directional nature of the laser would make UAV control signals virtually impossible to detect, depriving an adversary of indications and warning of UAV employment via signals intelligence (SIGINT). Additionally, a laser control system would be much more difficult for an adversary to jam or spoof.

- The account of Al Razi's flight test indicates that it was successful within line-of-sight range and, if combined with a vehicle with autonomous guidance capability, could have provided the Iraqis the means to operate more covertly with their UAVs without laser range limitations.
- If the reports of Huwaysh's cancellation of the project are accurate, either Huwaysh obviously did not appreciate this potential operational advantage, or he did not consider it important.

Republican Guard Major Anmar's attempt to use the Al Musayara-20 like a cruise missile shows an awareness of the weapon potential of UAVs; however, the use of a conventionally armed UAV raises questions as to its actual use. Although the information we have indicates Anmar intended to arm the UAV with conventional explosives (probably in place of the recovery parachute), this UAV does have the

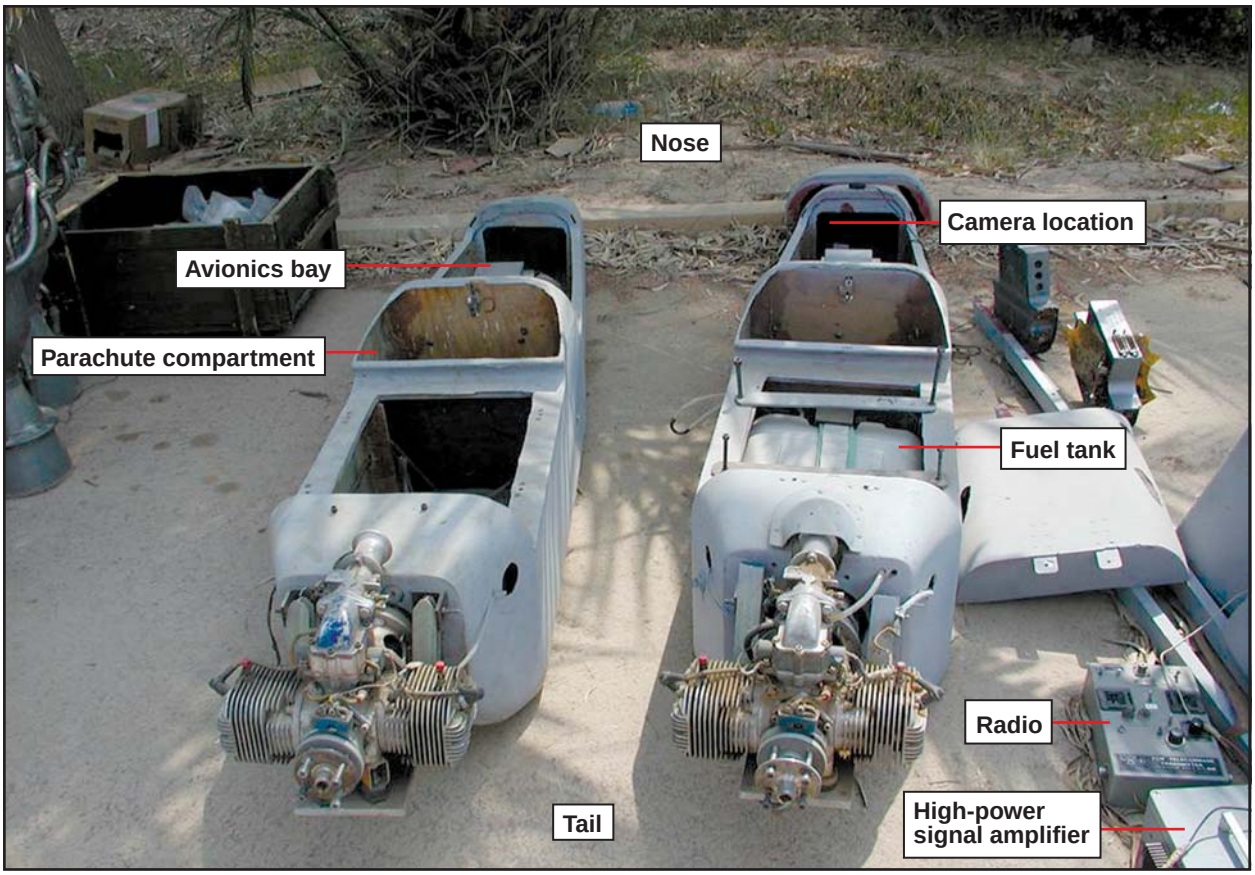

Figure 24. *Al Musayara-20 components.*

range, payload, guidance, and autonomy necessary to be used as a biological weapon delivery platform ***if*** the Iraqi leadership made a decision to use it in this way ***and if*** a suitable dispenser system were available. ***ISG judges that the Al Musayara-20 does not have sufficient payload capacity to serve as an effective CW platform.***

- A BW platform conversion would require replacing the recovery parachute with a dispenser system and agent and limiting the UAV to one-way delivery missions. The same guidance system that allows the Al Musayara-20 to be programmed to automatically image targets of known location would be capable of being programmed to activate a BW dispenser at a known location.

- ***ISG has not found evidence of intent or research and development activity associated with using Ibn-Firnas small UAVs as WMD delivery systems.***

Al Quds UAV Program

Background

Information uncovered by ISG reveals the Al Quds UAV program began in late 1999 or early 2000 when Dr. 'Imad 'Abd-al-Latif Al Rida' submitted a proposal to Hadi Taresh Zabun, DG of the MIC Research Directorate, that claimed he could develop a better UAV than those being developed by Ibn-Firnas, according to Huwaysh and an official in the Iraqi UAV program. However, in late 1999 MIC recalled Dr. 'Imad from retirement and instructed him to renew Iraq's development of small UAVs, which had stalled after Dr. 'Imad's retirement in 1997.

- ***Huwaysh stated that at approximately the same time Dr. 'Imad proposed his UAV development program, the Iraqi military asked MIC for a UAV capable of carrying 30-kg and 100-kg payloads for***

communications and radar jamming equipment. A high-level MIC official confirmed the 30-kg and 100-kg payload goals and that they were intended for jamming or direction-finding equipment.

- Reportedly, Dr. 'Imad had no knowledge of the intended mission or payload for the aircraft he was developing; he was simply given a payload goal, and one report indicates he was not given the 100-kg goal until August 2002.

Huwaysh reported that, as part of Saddam's "Long Arm" policy, he demanded a 24-hour endurance UAV (estimated range of 2,500 km) in response to Israel's high-endurance UAV capability, which is similar to Dr. 'Imad's reported belief that Saddam wanted a UAV on par with those of the US. No direct evidence links the Al Quds program to these stated range and endurance goals; the best indication of the actual performance goal for Al Quds is a June 2002 memorandum from MIC Deputy Director Muzahim to Huwaysh containing a project update on Al Quds which says, in part, "…'Imad 'Abd-al-Latif indicated that the only part left from the project is the instructions of the esteemed minister to increase the flying timing to four hours…"

- When confronted with this memorandum, Huwaysh denied that he ever set such a performance goal for Al Quds and claimed to have never seen the memo. On the other hand, Muzahim authenticated the memo.

MIC established the Al Quds program in a hangar at Al Rashid Airfield, and development work began in January 2000. Dr. 'Imad requested that the program not be under MIC control, but Huwaysh refused and instead proposed a relationship where MIC would maintain budgetary and administrative control through Ibn-Firnas, but Dr. 'Imad would have managerial discretion over the program.

- This arrangement allowed Dr. 'Imad to hire his own research and development staff of 12-20 people (reports differ on its size) and also obligated Ibn-Firnas to provide material support to Al Quds as required.
- It appears that the Al Quds program was placed under the MIC's Special Projects Office (a.k.a. Master Subjects Office), which was created by Huwaysh for key projects requiring high-level attention and financial support.

Multiple sources reported that the initial Al Quds efforts involved attempts to develop a jet-powered UAV that would meet the range and payload requirements. These efforts reportedly included evaluation of turbostarter engines from older Russian MiG and Sukhoi fighter aircraft in Iraq's inventory and the Microturbo turbojet engine from the Italian Mirach-100 RPV that Iraq had obtained prior to 1990.

- The MiG and Sukhoi turbostarter were ruled out due to excessive fuel consumption, and so development proceeded with the Microturbo engine.

The first Al Quds prototype, Quds-1, was 5-6 meters long and had a wingspan of 10-14 m. One source described the prototype as appearing "stealth" like but said radar cross-section reduction was not a goal of the program. Subsequent UNMOVIC photographs (see Figure 25) of later Al Quds prototypes reveal a faceted fuselage somewhat reminiscent of the US F-117A. Because of initial difficulties in obtaining servos and associated remote-control equipment, the initial prototype had a cockpit, flight controls and control, system for manned flight tests

- Unspecified difficulties with the engine forced Dr. 'Imad to abandon plans to conduct a manned flight test, and the jet powered Al Quds prototype never flew.

- Reportedly, in early 2003 this prototype was dismantled and the components spread through the aircraft scrap yard at Al Rashid and covered with palm leaves to conceal them from UN inspectors. One Iraqi scientist considered the entire attempt to produce a jet-powered UAV to be a "fraud."

A high-level official in the Iraqi UAV program denied that a large, jet-powered UAV was the initial intent of the program, and claimed instead that, early in the program, engineers were having trouble fabricating symmetrical wings for the prototypes. Asymmetrical

wings would cause the aircraft to roll on takeoff, possibly causing a crash before the operator could correct the roll. The large, jet-powered, manned vehicle was reportedly intended only as a testbed for wing symmetry with a pilot on board to correct the roll tendency.

The difficulties with the initial Al Quds prototype, combined with a lack of wind tunnel facilities to test the designs, prompted Dr. 'Imad to construct scaled-down versions of the prototype for open-air aerodynamic testing. According to an official at Ibn-Firnas, 10 subscale prototypes were produced for testing. The official further asserted that Dr. 'Imad made a decision to focus on the smaller UAVs to compete with the Al Musayara-20 reconnaissance UAV being developed by Ibn-Firnas.

- These smaller subscale UAVs were the RPV-20a vehicles shown to UNMOVIC inspectors at Ibn-Firnas in early 2003.

- Reportedly, Dr. 'Imad never informed MIC management of his decision to abandon the larger UAV development to focus instead on the smaller RPV-20a.

Both Huwaysh and Muzahim believed Dr. 'Imad was continuing to work on the large-payload UAV until early 2003 when they convened a program review. At the review, Huwaysh chastised Dr. 'Imad for wasting money on the program, hiring personnel without MIC approval, and for not achieving the stated goal of the program. Huwaysh also questioned the utility of developing a competitor to the successful Al Musayara-20.

- Huwaysh claimed that he gave Dr. 'Imad 30 days to achieve progress toward the stated goal or the program would be terminated.

A high-level official at Ibn-Firnas provided a description of events somewhat different from Huwaysh's statements, claiming that the 100-kg payload requirement was not levied on the Al Quds program until August 2002 when Muzahim stated MIC did not need both Dr. 'Imad and Ibn-Firnas to produce small UAVs. The source suggested that Dr. 'Imad did not know what the 100-kg payload requirement was for, but speculated that Muzahim wanted to install the reconnaissance system from the Mirage fighter in the UAV.

Saddam's "Long-Arm" Policy

Long-range UAV programs along with long-range missiles formed part of Saddam's "Long Arm" policy.

This policy was in direct response to:

- *the inability of Iraq to acquire new fighter or bomber aircraft.*

- *Iraq's inability to counter its enemies' anti-aircraft missile technology.*

- *The vulnerability of Iraq's air force.*

The policy provided for the transfer of funds that were destined for purchases of new aircraft and equipment to the building of UAVS and missiles.

- ***ISG judges that the claims for the asymmetrical wing testbed and the late requirement for a 100-kg payload are associated with the source's unwillingness to admit initial failure with the jet-powered prototype.*** The weight of evidence indicates that the 100-kg payload requirement for electronic warfare applications was levied at the beginning of the program, not over two years later.

- Further, Huwaysh is insistent that 30-kg and 100-kg payload capabilities were Al Quds program goals from the beginning.

In November 2002, MIC ordered the Al Quds program moved from Al Rashid airfield to Ibn-Firnas so that Dr. 'Imad could receive additional help from Ibn-Firnas personnel. According to a high-level official in the Iraqi UAV program, this move followed earlier complaints by Huwaysh that Dr. 'Imad was jumping from project to project without showing signs of progress. This allegation is supported by a source who worked for Dr. 'Imad on Al Quds and said Dr. 'Imad often switched projects in mid-stream, disrupting employee work schedules and never seeming to finish anything.

- According to a source associated with the Al Quds project, Dr. 'Imad accepted many projects in the belief that the more projects his staff undertook the more money they could make. This tendency often required employees to work up to 22 hours straight in order to show any progress on a project.

- An engineer at Ibn-Firnas reported that the reason for the move from Al Rashid to Ibn-Firnas was MIC concerns that UNMOVIC discovery of a separate, undeclared UAV program would cause trouble for the Regime.

The Al Quds program was declared to the UN in Iraq's 15 January 2003 semi-annual declaration. Documentary evidence obtained by ISG indicates that the Iraqis claimed to the UN that the "unmanned aerial vehicles of two types 20a and 30a" were "an idea that began in August 2002; and they announced it on 2003/01/15 according to the Resolution No. 715 (1991) of the Monitoring Plan."

- The document further indicates that UNMOVIC inspected this program four times, on 19 December 2002, 2 January 2003, 10 February 2003, and 4 March 2003.

- Reportedly, UNMOVIC inspected the Al Quds program five times while it was at Ibn-Firnas.

Another source with direct access reported that, during UNMOVIC inspections, Al Quds workers were told to each take home components from the Al Rashid workshop for safekeeping until told to return them. Similar procedures were reportedly used to disperse equipment prior to the anticipated US air strikes. Regardless, the documented pre-OIF Iraqi claim that Al Quds began in August 2002 when it actually began in late 1999/early 2000 possibly reveals a specific intent to conceal the program from the UN.

Characteristics

Reportedly the eight subscale Al Quds/RPV-20a (please refer to Figure 25) prototypes had a 4.8 meter wingspan, a 15-kg payload to be carried in a one-square-foot internal compartment with a 24-volt power supply, a 70-kg maximum takeoff weight, and were powered by a 100-cc, two-stroke, two-cylinder, nine-horsepower pusher propeller engine.

- The first test flight of the subscale prototypes took place in April or May of 2000. The first two subscale prototypes were fitted with landing gear and took off and landed from a runway.

- Subsequent prototypes were launched from the roof of a pickup truck and recovered by parachute.

A high-level Ibn-Firnas official referred to these eight prototypes as Quds-1 through Quds-8 and did not acknowledge the jet-powered version described by other sources as "Quds-1." However, there was no Quds-9, and the next aircraft in the series is the Quds-10 or RPV-30a which is described next.

Dr. 'Imad began development of the Quds-10/RPV-30a in November 2002 (presumably after the move to Ibn-Firnas). This RPV had a wingspan of 7.22 meters with a maximum takeoff weight of 130 kg and was intended to demonstrate the use of a pusher/puller engine configuration. In order to speed and simplify construction of the aircraft, an L-29 drop tank was used for the fuselage.

- This aircraft flew only once, on 13 January 2003, remaining for 12-14 minutes in the airfield traffic pattern. Like the RPV-20a, Quds-10 was truck-launched but landed conventionally on the runway.

An Ibn-Firnas engineer claimed that Dr. 'Imad's primary motivation for developing the RPV-30a was to surpass the performance of Ibn-Firnas' Al Musayara-20, which had flown a 500-km circuit in June 2002. The engineer reported that Dr. 'Imad claimed the lighter structural design of the RPV-30a, depicted in Figure 26, would give it a maximum flight time of over six hours, exceeding the program goal of four hours.

As with the Ibn-Firnas UAV programs, the Al Quds UAVs were intended to be capable of autonomous flight using global positioning system (GPS) navigation and a preprogrammed autopilot. The procurement network for avionics components for Al Quds was through Ibn-Firnas and was the same as that described in the previous section. However, the Al Quds program never progressed to the point of attempting a preprogrammed autonomous flight and never actually received the Micropilot MP2000 or 3200VG autopilots used in the Al Musayara-20.

Missions

Huwaysh, Minister of Military Industrialization, and a former Ibn-Firnas engineer all reported electronic warfare missions for Al Quds UAVs. Electronic warfare missions include direction finding/signal intercept or communications and radar jamming. Huwaysh provided the most specific information, saying that an important lesson learned from the Iran-Iraq war

was the importance of being able to intercept and jam enemy communications and radar signals.

- Huwaysh provided a credible description of the value of UAVs for this role, discussing how they can be flown over enemy territory to get close to their targets, improving intercept and jamming effectiveness. Also, being cheap and unmanned, it would not be a major problem if they were shot down.

- An Ibn-Firnas engineer speculated that either the Al Milad or Al Salam companies would develop the electronic warfare payloads; Huwaysh was specific that Al Milad was the developer.

A number of other sources indicate the intended payloads for the Al Quds UAVs were direction finding, communications, and radar jamming, as well as reconnaissance equipment.

- Reportedly Dr. 'Imad did not know the intended payloads for his vehicles. Dr. 'Imad was only involved in developing the flight vehicle, but speculated that the payload would be reconnaissance equipment adapted from the Mirage fighter aircraft.

- ***ISG judges the 30-kg payload variant would probably be sufficient for a passive receiver for communication or radar signal interception and direction finding, but the 100-kg payload would probably be required to house the transmitter and receiver required for a jamming platform.***

- Two lower level sources, one with direct and the other with indirect information on Al Quds, agreed with the reconnaissance mission of Al Quds, but the indirect source added that the Al Quds engineers were directed to leave an empty compartment in the fuselage approximately 40 cm wide by 70 cm long by 50 cm deep for an unspecified purpose. ***ISG judges this is probably the recovery parachute compartment.***

Conclusions

The evidence accumulated by ISG indicates the Al Quds program was an initiative to meet an Iraqi military desire for airborne electronic warfare platforms. The overall program goal for Al Quds was to produce UAVs with 30-kg and 100-kg payload capabilities for communications and radar intercept and jamming missions.

ISG has uncovered no information connecting the Al Quds UAV program to delivery of weapons of mass destruction. However, successful development of the Al Quds UAVs would have provided Iraq with vehicles inherently capable of delivering biological (30-kg or 100-kg payload versions) or chemical (100-kg payload version) weapons. All of the prerequisites—range, autonomous programmable guidance, and payload—would have been present, ***if*** the Iraqis made a decision to use them for this purpose ***and if*** they developed a suitable agent dissemination system. However, ISG has uncovered no evidence of either made to order dispenser development or intent to use Al Quds for WMD.

The program began in late 1999 or early 2000 but was not declared to the UN until the January 2003 semi-annual declaration, after Iraq agreed to re-admit UN inspectors. A completed Al Quds UAV with a range capability beyond 150 km likely would constitute a violation of UN sanctions. However, when terminated by OIF, the program had not matured to the point where it achieved its full performance goals.

Procurement Supporting Iraq's Delivery Systems

Iraq used covert procurement methods to acquire materiel that was either banned or controlled under UNSCRs 661, 687, the Annexes to the Plan approved by UNSCR 715, and the Export/Import Mechanism approved by UNSCR 1051. ISG judges that these efforts were undertaken to reestablish or support Iraq's delivery systems programs. The period from 1998 to the start of OIF showed an increase in Iraq's procurement activities, and it is in this period that ISG believes Baghdad made its most serious attempts at reconstituting delivery system capabilities similar to those that existed prior to 1991.

Desert Storm and the various UNSC Resolutions led to the near destruction of Iraq's surface-to-surface (SSM) missile force and production infrastructure.

Figure 25. *Al Quds RPV-20a.*

Iraq began building its permitted missile design and manufacturing capabilities, including the ability to produce limited quantities of certain chemicals used in rocket propulsion.

- By the end of the 1990s, as was the case prior to Desert Storm, Iraq had the ability to design and build many of the necessary systems for an SSM with the exception of complete liquid-propellant rocket engines and guidance and control systems.

- According to a former MIC executive with direct access to the information, Iraq overcame these deficiencies by implementing a covert procurement system. Iraq used this system to buy restricted items from foreign sources through third party countries. These items were controlled by UNSCR 661 and 687, which put sanctions in place to prevent the export of certain goods, particularly military equipment, to Iraq.

- ***Many of these procurement activities started in 1998 after the UN inspectors were expelled from Iraq.*** (NOTE: For a complete description of Iraq's procurement process, refer to the "Procurement: Illicit Finance and Revenue" section of the ISG report.)

From 1991 to 1996, Iraq began establishing contacts and making limited purchases of controlled delivery system-related items. The initial efforts were undertaken in an environment of massive civil engineering work to rebuild Iraq's war-damaged infrastructure and while the UN inspection Regime was still an unknown quantity. In addition, strenuous efforts were devoted to rebuilding Iraq's armed forces to counter any threat from Iran.

ISG has uncovered documentary evidence and personal statements suggesting that, despite UN restrictions, Iraq entered into discussions with both Russian entities and North Korea for missile systems, though there is no evidence to confirm that any deliveries took place.

- Sources and documents suggest that Iraq was actively seeking to obtain the SS-26/Iskander missile from Russia.

- Document exploitation has revealed that Firas Tlas, the son of former Syrian Defense Minister Lieutenant General Mustafa Tlas, visited Iraq in July 2001 and discussed a variety of missile systems and components that he could supply through Russia. Firas offered to sell Iraq the S-300 SAM and the 270-km-range SS-26/Iskander-E short-range-ballistic missile, or to provide assistance to help Iraq produce the Iskander. Firas claimed that he had previously met with Izakoff, the former Defense Minister of the Soviet Union, who told him that his [Izakoff's] friend owned documents for "TEMPS" missiles, called "Sterlite" in the West. Reportedly,

Izakoff said the missiles had a range of 1,500 km and were very accurate. Tlas said Izakoff claimed that Mikhail Gorbachev destroyed the missiles, but that Izakoff could supply the documents so that Iraq could produce them. According to Firas, Izakoff said that Dimitrof (sic) (a close friend of the President) presented the subject to Russian President Putin, and President Putin agreed to provide assistance.

- Huwaysh claimed that Iraq had contacted both Syrian and Russian entities to discuss Iraq acquiring the Iskander missile in 2002. Russia would not export any military hardware without an end user certificate signed by the issuing government agency, which is the capacity in which Syria would have served.

NOTE: The TEMP-S is known in the West as the SS-12 Scaleboard and has a range of 900 km. These were destroyed under the Intermediate Nuclear Forces Treaty signed in the late 1980s.

- ISG recovered documents containing contract and money flow information concerning illicit trade between Iraq and North Korea. These documents show that, late in 1999, senior officials in Iraq, including 'Abd Hamid Mahmud Al Khatab Al Nasiri (the presidential secretary), the Director of the Iraqi Intelligence Service (IIS) began to discuss establishing trade with North Korea. In December 1999, Huwaysh formally invited a North Korean delegation to visit Iraq. The Iraqis and North Koreans decided that a face-to-face meeting would be held on or about 8 October 2000 in Baghdad. The North Korean Chang Kwang Technology Group was identified as the technology supplier and the prime technical mediator for the North Korean side. After an exchange of several communiqués, the representatives from both countries agreed to a list of specific subjects that would be discussed at the meetings, including technology transfer for SSMs with a range of 1,300 km, coastal protection missiles with a range of 300 km, and the possibility of North Korean technical experts working inside Iraq.

- A set of memoranda recovered by ISG shows that a high-level of dialogue between Iraq and North Korea that occurred from December 1999 to September 2000 led to plans for a North Korean delegation to secretly visit Iraq in October of 2000. Among the topics for discussion was the supply of "technology for SSMs with a range of 1,300 km and Land-to-Sea Missiles (LSMs) with a range of 300 km". During the course of discussions with Iraq, the North Korean side acknowledged the sensitivity of transferring technologies for these missiles but indicated North Korea was prepared "to cooperate with Iraq on the items it specified". ***There is no evidence, however, that the missiles were ever purchased.***

To improve its delivery system capabilities, Iraq sought technical experts from other countries to provide assistance. Much of the foreign assistance for the Al Samud missile program came from experts in Russia, but Iraq did receive assistance from other countries. According to some sources, this assistance was often not sanctioned by the home countries of the missile experts providing the aide.

- According to Huwaysh and an Iraqi computer specialist with direct access to the information, in 1998 MIC entered into a contract with a company called Babil to hire Russian missile experts as consultants. Babil would hire the experts, who then traveled to Iraq and worked on Iraqi missile programs, particularly the Al Samud. The initial value of the contract was approximately $11 million. That September, the Babil Company sent to Iraq missile experts from Russia who came from various universities, research institutes, factories, and production organizations. The experts were paid a cash salary of $2,000 each month they worked in Iraq.

- These individuals were in Baghdad for approximately three months starting in September 1998 and worked at locations physically separated from the actual production facilities. While there, they engaged in discussions with the Iraqis and drew up plans related to missile development and production. Upon returning to Russia, they continued to assist Iraq and were visited in Russia by various Iraqis.

- Huwaysh claimed that experts from Russia provided assistance to Iraq's missile programs beginning in 1998. In October 1999, the Russian experts provided technical reviews for the Al Samud program over a six-month period. This review included evaluations of the entire missile production system. These experts continued to provide assistance to the

Figure 26. *Al Quds RPV-30a.*

Al Samud program even after the review by providing a package of design calculations for liquid-propellant missiles and drawings for an inertial navigation system (INS). Huwaysh said UNMOVIC inspectors did not detect the experts from Russia during a site visit in 2002. Huwaysh speculated that if the Russian government found out that the experts were working in Iraq, they would probably have been punished, implying that the Russian government had not sanctioned these activities.

- A former Iraqi rocket motor test engineer claimed that experts from the FRY were involved in the development of the Al Fat'h missile system. Their involvement included analyzing instruments on the rocket motor test stand and providing an INS that was considered inadequate and of poor quality.

- A former senior executive in MIC who had direct access to the information admitted that, in 1999, Iraq signed a technical assistance contract with a commercial cover company, that operated outside of Belarus. The assistance included providing improvements to unidentified Iraqi missile systems. The contract also stipulated that experts from Belarus would maintain a semi-permanent presence in Iraq while the contract was in effect. According to the source, the head of the Belarusian delegation was an individual related to the office of the president of Belarus, that suggests that the government of Belarus may have been aware of this activity.

Numerous source admissions and documents have surfaced, which show some of Iraq's efforts at acquiring guidance and control components for its various missile systems. Because of its inability to successfully indigenously produce such complete components, Iraq was heavily reliant upon foreign suppliers to provide such items as accelerometers and gyroscopes.

- Two scientists in the Iraqi missile program provided information concerning Iraq's attempts to improve missile accuracy to ISG, both of whom had direct access to the information. In 1999, Al Karamah signed three contracts with companies from Russia for G&C technical assistance and equipment. The contracts' terms were as follows:

– The first contract was for approximately 25 inertial navigation systems designed to input to the Al Samud guidance system. They were a modernized version of the Scud guidance system and contained two MG-4, dual-axis flexible gyroscopes, two AK-5

Possible Connections to Terrorist/Insurgent Groups

ISG uncovered evidence of a possible connection between Al Quds program director 'Imad 'Abd-al-Latif Al Rida' and terrorist/insurgent organizations. In December 2003 after Coalition forces captured Saddam Husayn, a source who worked on Al Quds claimed that Dr. 'Imad had told him that four Al Quds UAVs were to be used as "flying bombs" to assassinate Israeli Prime Minister Ariel Sharon.

- *According to the source, four UAVs were to be given to a former Hamas member named "Abu Radin" who was a friend of Saddam Husayn. Abu Radin, who was no longer loyal to Hamas, would take the UAVs to Jordan, install 5 kg of C4 explosive, and use them to attack Sharon at the Wailing Wall in Jerusalem.*

- *Although uncorroborated, this story is similar to the well-documented Iraqi plan to use the Al Musayara-20 UAV as a "flying bomb."*

Additionally, a document obtained by ISG reveals that on 23 December 2000, Dr. 'Imad signed a memorandum with the Air Force and senior members of the Fedayeen Saddam agreeing to develop helicopter UAVs for the Fedayeen Saddam. This memo stated that the project had been coordinated with Huwaysh and the work would be a cooperative effort of MIC, the Air Force, and Fedayeen Saddam.

- *During initial testing, the UAV was difficult to control and the test deemed a failure. As a result, all work was suspended on the helicopter UAV project. The prototype was destroyed by cruise missiles on the third day of OIF.*

Huwaysh vehemently denied that he was aware of this effort, that he had authorized Dr. 'Imad to engage in it, or that it was an approved MIC project.

accelerometers, one aligned on the yaw (lateral) axis to correct for the effects of wind drift in the trajectory, and the other aligned along the axial (thrust) axis to derive the cut-off velocity for thrust termination to control the missile's range. The contract also required delivery of approximately five assembled and 20 unassembled pseudo-Inertial Measurement Units (IMUs) in addition to some guidance test equipment.

– The second contract was for approximately 100 modern, strapped down G&C systems that incorporated two, dual-axis flexible gyroscopes and three orthogonally configured accelerometers, which were also to have a digital output. The contract was amended to include an on-board flight computer and control system. The G&C systems on this contract were also designed to work in the Al Samud guidance units and were smaller than the ones listed in the first contract. Other items specified in the contract include individual parts such as: MG-4 gyros (approximately 30) and AK-5, A-15 and A-16 accelerometers (between 50 and 60). NOTE: Approximately 10 AK-5 accelerometers were received in June 2000 and another five to 10 in January 2001. The contract also included test equipment; e.g., servo test units, a single axis rate table, a single axis vibration tester, an environmental chamber, and a test unit for an optical dividing head.

– The third contract was for the purchase of eight IMUs, with fiber-optic gyroscopes, and four IMUs with ring laser gyroscopes. These systems were destined for the Al Karamah and Al Milad companies and were intended for use in the Al Samud and the Al Fat'h missile systems. Up to seven of the guidance systems were delivered to the Al Karamah General Company in the second half of 2002. All of the G&C systems and related components were stored at the Al Quds Factory of the Al Karamah General Company immediately before OIF. Although some examples of this hardware were recovered, the Al Quds Factory itself has been completely looted and no items remain.

Figures 27 and 28 depict some of the many guidance items recovered by ISG; Figure 29 Shows an Actuator stepper motor.

- Recovered documents provide details of Iraqi contracts for SSM technical assistance and missile-related hardware. According to these documents, in 1999 the Al Basha'ir Trading Company of Iraq began a series of contracts for G&C equipment, technology, training, and missile design training with the Infinity DOO Company from the FRY. ***ISG has not been able to confirm the delivery of the items specified in the contracts.***

- A former high-ranking official in MIC recalled that, at the end of 2000, Iraq signed contracts with North Korea worth at least $9 million. Iraq made a downpayment of $1.3 million. Some of the contracts specified providing G&C systems, inertial navigation systems, and on-board computers intended to improve the accuracy of SSMs having an operational range of 150 km or less. Iraq also sought to purchase gyros and accelerometers and asked if they could purchase existing SS-21 Tochka components. According to the source, Iraqi missile personnel believed that Tochka components would provide greater benefit to the solid-propellant Al Fat'h system than the liquid-propellant Al Samud.

– ISG recovered contracts between North Korea and Iraq related to guidance and control components. According to the contracts in late in 2001, an eight-person delegation from North Korea visiting Iraq reached agreements to sign six contracts to improve Iraq's missile system capabilities. One of the contracts was between the Al Karamah General Company and the Hesong Trading Corporation, North Korea, for the purchase of potentiometers (used in G&C systems), missile alignment equipment (pre-launch), batteries, and test stands for servos and jet vanes used on SSMs. Also, technical assistance was to be made available if required by Iraq. The equipment was to be delivered via Syrian ports within 9 months of contract initiation. ***ISG has been unable to locate any of the delivered equipment.***

– ISG gleaned the following information from acquired documents concerning contract number six between Al Basha'ir Trading Company Ltd of Baghdad and Infinity DOO of Belgrade, FRY. Contract number six, apparently signed 19 January 2001, for a total cost of $2,600,251, was for guidance and control testing equipment and training courses. ***ISG has been unable to confirm that these items were ever delivered.*** The test equipment was as follows:

– test stand designed for static testing of dynamically tuned gyros.

– test stand for solid state accelerometer static testing.

– an OMEGA-5 interference test stand for testing gyro rigidity and drift.

– equipment for developing homing and proximity fuzes.

– software for research and development of all systems.

– hardware-in-the-loop simulation software.

– and SSM simulation software.

- The following are excerpts from documents received by ISG. The information is related to contract number eight which is between Al Milad General Company of Baghdad and Infinity DOO of Belgrade, FRY concerning guidance and control equipment. ***ISG has been unable to confirm that these items were ever delivered.*** Contract number eight, signed on 19 January 2001, for a total cost of $183,480, was for:

– the design of an on-board computer system capable of withstanding 20 G's of acceleration and 40 G's of shock.

– a two-week training course for customer experts.

– a complete set of design (calculations), technical and technological documentation along with qua fication testing procedures for the computer.

- A former high-ranking official in MIC said that, in mid-2001, the Technology Transfer Department of the IIS procured between 10 and 20 gyros and accelerometers from China for approximately

$180,000. The items were intended for the G&C system of the Al Samud missile. The gyros were of the resonant type with a drift rate of ½ degree per hour. The source indicated that the Iraqis were never able to use the gyros and accelerometers because the packages were incomplete and therefore inoperable.

- An Iraqi scientist with direct access to the information claimed that entities in the FRY in 2002 offered to supply Al Milad with a navigation system for the Iraqi Jinin program (a cruise missile based on the HY-2). All requirements for the Jinin project were communicated to the foreign vendors directly.

- According to an Iraqi national with indirect knowledge of proscribed equipment smuggling, Wi'am Gharbiyah, a Palestinian businessman, successfully smuggled missile gyros into Iraq from Russia via Syria in 2002. Gharbiyah, whose earlier attempt to illegally import gyros from Russia to Dr. Muzhir of Al Karamah was foiled in Jordan due to detection by the UN in late 1995, used one of his contacts to propose to the Iraqi government to sell approximately 400 components containing gyroscopes and accelerometers in 2001. Using the IIS front company Al Karradah, the components were successfully delivered to Al Karamah through Syria in July 2002. ***ISG has not been able to confirm that this transaction occurred.***

- ISG has uncovered evidence that Iraq had numerous contracts with Dr. Degtaryev, a Russian missile guidance expert and the head of SystemTech. ***ISG has been unable to confirm whether these contracts were fulfilled.***

– Huwaysh claimed that Dr. Degtaryev was subcontracted through the Belarusian firm Infobank to build 3 guidance sets for the Al Samud, but these were detained during shipment through Jordan. Iraq then placed an additional order for 3 guidance sets, that were successfully delivered. Huwaysh stated that these sets were never used because they were sent to a facility for replication but they were unable to duplicate them by the time of OIF.

– A former Iraqi senior executive in MIC stated that the Al Karamah General Company signed and executed several contracts with Dr. Degtaryev. Through the ARMOS Company, Al Karamah signed contracts with Degtaryev. He visited Iraq several times along with other experts and executed several contracts with the Al Milad, Al Karamah, and Al Harith companies valued at $20 million.

– According to documents ISG retrieved from the office of MIC, Iraq signed contracts for missile guidance electronics with the firm SystemTech run by Degtaryev. ***Although ISG has been able to recover some of the delivered components, ISG has not confirmed that these contracts were fully executed.***

Iraq relied on foreign suppliers for production-related machinery for use in its Al Samud programs. Iraq's success at acquiring this machinery probably affected the production rate of these missiles. Russian entities were the main suppliers of machinery and tooling, though other suppliers may have played a role.

- A high-level Iraqi official and an Iraqi scientist claimed that, beginning in 1998, in addition to engineering and technical support, experts signed contracts to supply many of the pieces of equipment for the Al Samud program. This equipment included many of the production machines along with related dies, moulds, and fixtures for the Al Samud program. Two small automatic circumferential and longitudinal welding machines were sent from Russia. The Russians also provided jigs and fixtures that were made in Russia and then imported into Iraq.

- ISG learned through interviews with a former high-ranking official in MIC that, in June 2001, Iraq signed a contract with a company from Russia for machinery and equipment that was worth $10 million. The machinery included a flow former, furnaces, and welding machines. The flow former was tested in Russia and installed at the Al Samud site in Abu Ghurayb but was not used before the war. The original contract length was 18 months; however, it was extended because the work specified in the contract was incomplete. At the start of OIF, work on the engine fixtures for Al Samud II was 60-70% complete, work on the airframe design

was 50 percent complete, and work that would have contributed to the test and assembly of new engines was 40 percent complete. These projects were intended to help establish a proper production line for the Al Samud II because the missiles produced before June 2001 were not of consistent quality, which made them unreliable. The experts co-operated with the Iraqis until OIF. ***ISG has no evidence that the government of Russia sanctioned or approved these contracts.***

- A former high-ranking official in Iraq's ballistic missile program stated that, in 1999, Al Karamah signed a contract worth $1.6 million with a Russian company for Al Samud airframe production, assembly, and testing. According to the contract, the payments would be tied to item deliveries. The first payment of $100,000 would be paid after receiving the design drawings. The contract was modified in 2001 when the Al Samud missile diameter increased to 760 mm. By 2003 only 65% of the design drawings were received.

ISG judges that Iraq received at least 380 SA-2/ Volga liquid-propellant engines from Poland and possibly Russia or Belarus. Source claims corroborated by contract information support this judgment. This figure is also consistent with what Iraq declared to the UN.

- According to a high-level official in Iraq's missile program, Iraq received 280 SA-2 engines, some of which were secondhand and some damaged, from Poland through a company known as Evax. A majority of these engines reportedly arrived in 2002. Additionally, the source speculated that Iraq had possibly imported 100 SA-2 engines from Russia through an Iraqi company known as Al Rawa'a.

- A letter dated 2 July 2001 signed by Dr. Hadi Taresh Zabun, the head of MIC's procurement department, indicated that MIC had received approval to enter into contract with Evax for an additional 96 SA-2 engines under the same terms and prices as their earlier contract for 38 engines. Another document referenced a subsequent contract for Iraq to receive the remainder of the 200 engines they had ordered, 96 of which they had already received. This was followed by a letter dated 11 April 2002 from the Polish company Evax to the Deputy Minister of Military Industrialization, which states that a third shipment has arrived at the port of Tartus and is on its way to Baghdad (the Al Karamah General Company), comprising 32 Volga rocket engines and 750 pieces (pressure valve, air valve, servo, and miscellaneous other materials). The letter also states that a shipment of 104 samples is delayed in Poland awaiting the required inspection before they can be exported (comment: this may refer to the rest of the 200 engines in the contract).

- A source with indirect access to information claimed that, in December 2002, Iraq successfully procured either from Belarus or Russia, approximately 100 Volga engines and 380 missile thermal batteries. They then imported these items via Sudan and Syria by using a front company called Al Rawa'a. ***ISG has no evidence that these East Europeans countries either sanctioned or approved these transactions.***

Officials within Iraq's missile programs have disclosed information about Iraq's pursuit of carbon fiber technology for use in its solid rocket motor programs. Companies from Russia were Iraq's main targets for the acquisition of this technology.

- A former senior-level official in Iraq's missile program provided information about Iraq's attempts to obtain carbon fiber technology that is used for solid rocket motors such as the Al Fat'h. MIC began pursuing carbon fiber technology from Russia in the last quarter of 2002; this effort ran in parallel with work being accomplished by the Military Engineering College under contract to the Al Rashid General Company. Iraq's Military Engineering College and the Al Rashid General Company were responsible for Iraq's indigenous carbon fiber production efforts. Al Rashid was responsible for the solid-propellant motor case and the Iraqi Military Engineering College was responsible for the carbon fiber production lines. The contract, which included one carbon fiber filament winding machine, one mandrel manufacturing machine, one mandrel extraction machine, one high-powered cleaning machine used to remove the gypsum from the mandrel, and one curing furnace was not completed by the required date and an extension was granted. By the start of OIF, the majority of the components were finished.

Figure 27. *A-16 shipping container.*

Figure 28. *MG-4 gyroscope,*
AK-5 and A-15 accelerometers.

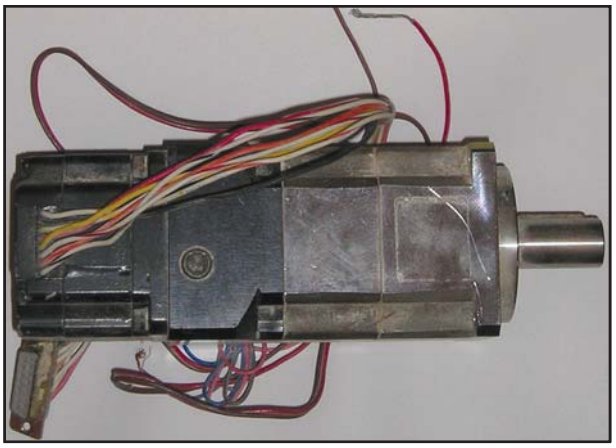

Figure 29. *Actuator stepper motor.*

- A former high-level official in MIC claimed that during the first quarter of 2003, an unidentified Russian company contacted the ARMOS Company to facilitate a visit by Iraqi researchers to the Russian carbon fiber production lines and have the experts from Russia provide technical assistance. MIC created a delegation, authorized by Huwaysh, to travel to Russia to speak with the technicians and visit the lines. The Iraqi delegation was canceled due to the start of OIF.

Iraq's inability to successfully produce all the chemicals necessary for propellants for its missile systems forced Iraq to acquire these chemicals from foreign entities. Iraq attempted to use a front company to mask these activities from international attention. ISG discovered numerous occasions in which Iraq attempted to acquire chemicals for use in their liquid-propellant missile program. ***ISG has not been able to confirm that contracts were ever agreed to for all these chemicals or if any agreed contracts were ever fulfilled.***

- Documents ISG recovered from the Baghdad offices of the Arabic Scientific Bureau (ASB) and Inaya Trading company describe solicited quotes from Chinese and Indian companies (including the Inaya Trading Company) for chemicals and materials used with liquid-propellant missiles. Some of the chemicals in which the ASB was interested were: Unsymmetrical Dimethylhydrazine (UDMH), Diethylenetriamine (DETA), Hydrazine, Hydrogen Peroxide, Xylidene, and Triethylamine. These chemicals are common fuels and oxidizers used in liquid-propellant engines. The documents do not, however, indicate whether any contracts were signed or material delivered, and, since the dates reported are late 2002, purchase of the chemicals may have been stopped by OIF.

- ISG has learned that in 2002 proposals were placed before MIC by the Al Anas Trading Agency Co., Ltd., through Dr. Nazar 'Abd-al-'Amir Hamudi, for amounts totaling hundreds of tons of many different liquid propellants, their constituents or pre-cursor chemicals. The information states not only was Iraq actively looking for stocks of propellants that were currently in widespread use but also that they were seeking tens of tons of more advanced, higher energy liquid propellants. ***ISG believes that, due to the start of OIF, these chemicals were never delivered.***

- A former executive in MIC told ISG that Iraq had wanted to purchase or produce AZ-11 liquid propellant because it is a more energetic fuel and produces greater thrust. Therefore, the Iraqis made several attempts to acquire AZ-11 fuel from the Ukraine but they were never successful.

Iraq also undertook efforts to improve its solid-propellant program by importing chemicals needed in the production of solid-propellants. ***Though ISG has not been able to confirm that contracts were ever agreed to for all these chemicals or if all of the contracts were ever fulfilled, ISG did discover large amounts of imported aluminum powder during a site visit to Al Amin Factory, part of the Al Rashid General Company.***

- Some 60 tons of imported aluminum powder, suitable for use in solid-propellant rocket motors, were discovered during an ISG site exploitation inspection of Al Amin Factory. ***At the then current rate of demand, this would have satisfied the requirement for hundreds of motors.*** Considerable quantities of other propellant materials had also been imported and were potentially available for use.

- A former high-ranking official in the Iraqi missile program who had direct access to the information claimed that Iraq purchased chemicals used in solid-propellant rocket motors. The official reported that, in 1999, the Al Rashid General Company purportedly placed orders for raw materials that are used in the production of solid-propellants for missiles. Among the orders was a purchase made from the Al 'Ayan Company, owned by Jabir Al Dulaymi, for six tons of ammonium perchlorate (AP) and six tons of aluminum powder. The Al 'Ayan Company purchased these items from a French company for Al Rashid. ***ISG has no evidence that the French government either sanctioned or approved this transaction.***

- A few officials have provided information about Iraq's dealings with the Indian firm NEC for chemicals for solid-propellants. ***ISG has no confirmation that the government of India either sanctioned or approved these activities, and Indian authorities arrested NEC's director, Hans Raj Shiv, in 2003 for his illicit activities.***

– According to Huwaysh, former Director of MIC, he had many business dealings with the Indian firm NEC. Huwaysh says that as late as April 2003, Hans Raj Shiv, the director of NEC, was working in NEC's Baghdad office. Examples of the Iraqi-NEC business relationship are: NEC supplied the Al Qa'qa'a General Company with a nitric acid production capability used in the production of explosives. Between 1999 and 2002, Iraq purchased from NEC at least 10 cells that were used to process sodium chloride, probably related AP production.

– ISG has learned from an Iraqi scientist with direct access to the information that, from 1999 to April 2003, Iraq procured from NEC Engineers Private, Ltd., the design and construction of AP processing facilities. AP is a major constituent of solid-propellants. The procurement included machine equipment, tools, and direct engineering assistance. This contractual relationship resulted in the construction of two AP production facilities. The Iraqis did most of the work on the first facility but NEC provided technical assistance, the electrolytic cells, and the centrifuges. This facility had an output capacity of 50 tons per year (NFI). The second AP facility, with a capacity of 180 tons per year, required much more involvement by NEC who provided the equipment, production technology, and engineering support. The Iraqi Al Faw Company was involved with the physical construction of this facility. ***ISG judges that these two facilities, if run at full capacity, would have produced sufficient oxidizer a year to manufacture 300 tons of propellant – more than sufficient to support Iraq's declared solid-propellant programs and enough to facilitate work on motors for new missiles.***

- According to a former high-ranking official in the Iraqi missile program, the Al Rashid General Company purchased raw materials for solid-propellant motors beginning in 1999. Among the items were:

– *356 tons of AP*. Six tons of AP from the Al Rayan Company, which was purchased from France; an additional 350 tons purchased from the following entities: NEC, which purchased the AP from an unnamed source; Al Sharqiyah, which purchased the AP from an unnamed purchased the AP from China; and Al Maghrib, which purchased the AP from France;

– *126 tons of aluminum powder*. An initial order of six tons of aluminum powder from an unidentified source; an additional 120 tons purchased from NEC and three Iraqi companies (Al Sharqiyah, Al Maghrib, and Al 'Ayan) who purchased it from France;

– *104 tons of HTPB*. An initial order of four tons of hydroxyl terminated polybutadiene (HTPB), a binder, purchased from the Al Taqaddum Company, which purchased it from an Italian company; and an additional 100 tons of HTPB from NEC, which purchased it from a United States company,

– *2 tons of methyl aziridinyl phosphine oxide (MAPO)* from NEC, which purchased it from China;

– *60 tons of dioctyl azelate (DOZ)* from Al Sharqiyah, which purchased it from a Japanese firm.

Infrastructure Improvements and Technology Developments

The steady improvement in Iraqi missile infrastructure seen during the Regime's "Decline" phase was accelerated after 1996 in the: "Recovery" and "Transition" periods. Iraq expended great efforts reconstituting destroyed or unusable equipment in order to restore required production and deployment capabilities for the Al Samud II and Al Fat'h. These capabilities could have been used to develop and produce missiles with ranges longer than allowed under UNSCR 687. No restraints were applied to achieving this objective, including clear breaches of international treaties and the use of foreign expertise and assistance.

Static Test-Firing Facilities

ISG judges that Iraq's existing static test facilities for liquid rocket engines and solid rocket motors were in no physical condition to continue to support development and testing of Iraq's liquid-propellant rocket engines.

- Iraq's existing liquid-propellant engine test stand at Al Rafah was designed to handle a single Scud-class engine of 13.5 tons of thrust, but, due to more than a decade and a half of usage, age, and bombing, was probably not capable for Iraq's needs. According to one Iraqi engineer, construction on a new test stand began by August 2001, and it was sized to handle an engine larger than the SA-2-class or Scud-class engine. However, while physically able to accept a larger engine, the facility was not capable of withstanding the thrust that such a large engine would normally be expected to produce. The engineer suggested the test stand could have been used to test clustered SA-2 engines. The facility was not commissioned by the time of OIF. ***ISG assesses the new stand with modifications was suitable for clustered engines.***

- Although various static test-firing facilities for solid-propellant motors existed at the Al Qa'qa'a General Company (Nu'man site), these were of smaller capacity in terms of both explosive and thrust rating than those at Al Mutassim (Yawm Al Azim). At Al Mutassim, the largest of 5 test cells had been upgraded to allow thrust levels of 50 tons to be safely tested.

Solid-Propellant Rocket Motor Case Manufacture

At Al Amin, an aging oven originally installed for the first stage of the proscribed BADR-2000 ballistic missile, which was "destroyed" by UNSCOM, was repaired. Iraq constructed a much larger annealing furnace, and an existing annealing furnace at a nearby Saddam General Company (now known as Al Ikha' Company) was used in the manufacturing process for the Al Fat'h motor. ***This annealing capacity greatly exceeded the requirements of the Al Fat'h and Al 'Ubur missile systems and provided Iraq with the ability to create motor casings greater than 1 meter in diameter and 6.5 meters in length, consistent with the plans now revealed for a larger, longer range missile.***

- During a site exploitation visit to Al Amin, ISG investigated the BADR-2000 aging oven that had been 'destroyed' by the UN and had been recomissioned for use in the production process for the Al Fat'h motor. To do this effectively, a cylindrical sleeve was inserted into the furnace to enable a better match with the 500-mm-diameter motor case. ***The aging oven was incapable of annealing 30CrMoV9 material of the Al Fat'h motor case.***

- Iraq built a new furnace that was capable of heat-treating a motor case about 1.25 meters in diameter with a length in excess of 6.5 meters. This furnace contained a fixture that could hold a motor case 1-meter in diameter. ***ISG could not determine if this furnace had been used or even commissioned.***

- Large annealing furnaces at an existing facility of the Saddam General Company were used to anneal solid-propellant rocket motor cases for the Al Fat'h missile.

Propellant Production

Iraq attempted to increase its solid-propellant production capability by repairing the prohibited 300-gallon mixers declared "destroyed" by the UN.

- While accounts differ, Iraq was reportedly able to repair at least one of the two 300-gallon mixers and two mixing bowls. Reports indicate that either one mixer was repaired to increase the existing mixing capability, or that both mixers were brought on line

to support the requirement for a larger motor for the long-range missile program.

- A cooperative source stated that the Iraqis immediately prior to the entry of UNMOVIC inspectors destroyed the 300-gallon mixers. Despite extensive searches, that included active source participation, ISG has not found physical evidence of mixers, parts, or debris.

Solid-Propellant Motor Casting Chambers

The capability to cast large solid-propellant rocket motors increased with the repair of two previously destroyed (and prohibited) casting chambers and the construction of an even larger chamber.

- A new, even larger casting chamber, approximately 1.56 meters external diameter by 6 meters deep, had been built for possible use in the production of a motorcase up to 1.25 meters in diameter. Because the chamber was built by Iraq and had not been used to produce proscribed items, UNMOVIC chose only to monitor the facility.

Production of Solid-Propellant Ingredients

Ammonium perchlorate (AP) constitutes the greatest mass of composite solid-propellant, and its availability was crucial to the future of all of Iraq's major solid-propellant missile programs. ***Planned production of propellant constituents would have enabled the production of motor quantities larger than known program requirements***.

- Iraq obtained assistance in the expansion of its AP production capabilities from NEC Engineers Pvt Ltd., an Indian Company, according to multiple sources. This facility was located at the former nuclear plant at Al Athir and was designed to produce 180 ton per year. However, this plant was not fully operational prior to OIF and produced only a limited quantity of AP.

- According to a high-ranking official in the Iraqi missile program, Iraqi universities attempted to revive the Hydroxyl Terminated Poly Butadiene (HTPB), a solid-propellant binder, plant at Al Ma'mun. This plant, purchased from Egypt in 1987, was supposed to supplement existing stockpiles. The source claimed that, although the plant had the necessary equipment, it never had the technology to use the equipment in HTPB production. ***If Iraq had been able to bring this facility on line, they would have reduced if not eliminated reliance on imported HTPB.***

- Some 60 tons of imported aluminum powder, suitable for use in solid-propellant rocket motors, was discovered during an ISG site exploitation inspection of Al Amin. ***At the current rate of demand, this would have satisfied the requirement for hundreds of motors.*** Considerable quantities of other propellant materials had also been imported and were potentially available for use.

Propellant Research

Iraq was undertaking a planned, long-term research program into solid and liquid propellants, in order to be self-sufficient in propellant-related chemicals denied to them by UN sanctions and to create higher energy propellants, which could enhance the performance of existing and future ballistic missile systems.

- In 2001, Iraq began an extensive program researching higher energy composite solid-propellant ingredients including nitronium perchlorate (NP), nitro-hydroxyl-terminated polybutadiene (HTPB), azido-HTPB, and ammonium dinitramide (ADN). The research was conducted in Basrah University and the Ibn Sina' Company. Only a few grams of each were manufactured and possibly delivered to Al Rashid, but no serious production efforts were undertaken. ***ISG has found no evidence that research into NP, nitro-HTPB, or azido-HTPB was ever declared to the UN. ISG judges that Iraq was unlikely to develop missiles in the near term using any of these higher energy solid-propellant ingredients***.

- Starting in the late 1990s, Iraq also conducted research, testing, and limited production of higher energy liquid propellants such as unsymmetrical dimethyl hydrazine (UDMH), AZ-11, AK-40, and 95%-99% pure hydrogen peroxide. This research

and pilot production was conducted at several facilities including Ibn Sina' Company, Mosul University, Al Kindi General Company, and Al Raya' Company. ***From all available evidence, ISG believes that Iraq was not able to manufacture large quantities of these propellants.***

- Starting in the late 1990s, Iraq also began research into production of propellants for its missile forces. These attempts at pilot production included xylidene, triethyl amine (TEA), nitrogen tetroxide (N2O4), and inhibited red-fuming nitric acid (IRFNA). ***While Iraq was somewhat successful at regenerating or producing some AK-20 (mixture of 80% nitric acid and 20% N_2O_4) and TG-02 (50-50 mixture of xylidene and TEA), they were unsuccessful at producing large quantities of these propellants or any new propellants. Iraq was reportedly successful in acquiring quantities of these chemicals from abroad for use in propellant production.***

Graphite Technology

Through its efforts to reverse-engineer SCUD missile designs before 1991, Iraq gained an understanding and ability to produce graphite nose tips that would satisfy the technical requirements of warheads that could be used on systems from short to very long ranges.

Graphite is used in ballistic missiles in areas that suffer high thermal and erosive stresses such as nose cone tips, solid-propellant nozzle throat inserts, and thrust vector control vanes.

- According to a high-ranking official in Iraq's missile program, the nose of the warheads for the Al Samud and Al Fat'h missiles were graphite and based on the warhead design for the Scud missile. ISG retrieved three Al Samud II graphite-tipped nose cones during site exploitations.

- A former military officer and engineer claimed that the graphite of the jet control vanes for the Al Samud proved capable of withstanding the intense heat and erosion during a vertical static test of the engine.

The procurement of graphite for the Iraqi ballistic missile program is well documented. The Arab Scientific Bureau, which was a front company seeking aerospace parts and chemicals for Iraqi state companies, tendered offers for graphite blocks. The Al Rashid General Company ordered 7.5 tons of graphite for 2003 and 2004, according to a contract document, and, during a site exploitation of the Al Amin Factory, ISG discovered two large wooden boxes containing two to three tons of graphite blocks.

Carbon Fiber Filament Winding

Starting in 2001, Iraq began a program to develop carbon fiber filament winding capabilities for use in weapons-related applications. This initiative only proceeded as far as the production of plain cylinders.

- According to several officials in the Iraqi missile program, Iraqi interest in carbon fiber technology was aroused in the 1980s when an Iraqi team including Husayn Kamil went to Brazil and paid approximately $80 million for the technical specifications and training for the ASTROS-II carbon fiber filament winding technology.

- A recovered memo dated 19 January 2001 documents a request by the Iraqi Al Basha'ir Trading Company to the FRY Company, Infinity DOO, for a filament winding production line with technology transfer.

- An Iraqi engineer stated that, in 2001, the Iraqi Atomic Energy Commission (IAEC) possessed an incomplete carbon fiber filament-winding machine that had not been used since 1990. The machine was moved from the Al Athir complex to the Military Technology College (MTC) in 2001 where it was to be repaired and then copied.

- By mid-2001, Huwaysh approved a missile-related carbon fiber winding production program and selected the 500-mm Al Fat'h solid-propellant motor case, nozzle, and end dome as the candidate for the carbon fiber filament winding initiative.

- During a meeting in February 2002, Huwaysh initiated an effort to seek foreign assistance in carbon fiber composite production, using the ARMOS Company.

- A high-ranking official in the Iraqi missile program recalled that, by the summer of 2002, a contract was awarded to the MTC to develop fiber winding machines with the ability of winding objects one meter in diameter and seven meters long, and the mandrel capacity was to support a 500-mm diameter 4 to 4½ meters in length. By the start of OIF the contract was still not complete.

- A former MIC official claimed that concurrent to the MTC filament winding machine contract, MIC pursued assistance from Russian entities in carbon fiber technology. In September or October 2002, a Russian expert reportedly visited MIC and agreed to a reciprocal visit in Russia on carbon fiber technology. A trip was planned for Iraqi researchers to visit Russian carbon fiber production lines and receive technical assistance. The trip did not take place due to OIF.

- MIC also examined importing carbon fiber raw materials from Europe while at the same time tasking a postgraduate student at Babylon University to research making carbon fiber raw materials from petroleum.

The properties of carbon fiber could provide a 30-40% weight savings over components made from steel. As an example, the Al Fat'h steel motor case, nozzle and end dome make up approximately 200 kg of the 1,050 kg total mass of the motor. A carbon fiber design could save approximately 60-80 kg of weight from the roughly 1,050 kg total weight. This savings could be applied to additional warhead capacity or towards increasing the range.

Ceramic Warhead Effort?

ISG has no credible evidence that Iraq was pursuing ceramic warheads for use as CBW warheads. Ceramic's poor heat-resistant properties negate its use with conventional, chemical, and biological warheads. While ceramic warheads may retain dimensional stability during aerodynamic heating, they also transfer this heat directly to the payload. Therefore, extremely elaborate techniques would be required to cool any CBW warhead and would, at least, require thermal insulation for conventional warheads. One source assessed by the collector as likely being motivated by financial incentives claimed that Iraqi scientists were working on developing ceramic warheads designed for filling with chemical agents and mounting on missiles within a few hours. The source added that the Badr General Company made "a few" of these warheads***. There is no evidence to support these claims, and ISG judges that the source's statements are not credible.***

- While ceramic materials are heat resistant and relatively inert to most chemicals, working with this material is complicated. The US and the UK investigated using ceramic warheads for ballistic missiles in the 1970s, but these investigations were not pursued.

- A ceramic warhead would have better in-flight dimensional stability during re-entry compared to ablative warheads. Dimensional stability during flight directly relates to aerodynamic stability and increased accuracy. However, increased costs associated with manufacturing and handling ceramic warheads outweigh the benefits.

- Producing consistent ceramic formulations is still an art, and machining ceramic materials to a desired shape on a consistent basis is notoriously difficult. Ceramic warheads must also be handled with care, which necessitates entirely new procedures for use and training.

ISG recovered ceramic nose cone pieces which were not sufficient to form a complete nose cone. However, initial examination of these ceramic pieces shows a right cone at the tip followed by a transition to an ogive shape, which is similar to a SA-6 nose cone. ***These may have been subscale models or may be totally unrelated to ballistic missiles.***

Proscribed Activities

ISG has substantial documentary evidence and source reporting indicating that the Regime intentionally violated various international resolutions and agreements in order to pursue its delivery systems programs. Sources with direct access have described missile projects with design ranges well beyond UN limits and ISG has research documents to corroborate these claims. Additionally, ISG has

exploited documents that confirm Iraq circumvented UN sanctions by illicitly importing components for use in its missile programs.

Violations of United Nations Sanctions and Resolutions

ISG has uncovered numerous examples of Iraq's disregard for UN sanctions and resolutions in an effort to improve its missile and UAV capabilities. These violations repeatedly breached UNSCR 687, 707, 715, 1051, 1284, 1441 and pursuant annexes and enabled Iraq to develop more robust delivery system programs.

Equipment Restoration

Multiple sources have highlighted Iraq's efforts to reconstitute equipment associated with past missile programs previously disabled or declared destroyed by UNSCOM. Accounts for the actual use of these restored items vary. ISG has been able to confirm the existence of some of this equipment, but not all of it.

Several sources with direct access have provided information about the successful repair of one of the 300-gallon solid-propellant mixers associated with the BADR-2000 missile project that were destroyed by UNSCOM in 1992 at Al Ma'mun. ISG has conducted site exploitation visits to the last reported locations of these mixers but has been unable to locate them.

- According to two high-level officials within the Iraqi missile program, one of the two 300-gallon mixers destroyed by the UN was repaired in 2002, but the other could not be repaired. The officials did not elaborate on what the mixer was used for.

- Husam Muhammad Amin Al Yasin, the former director of the NMD, stated that Huwaysh ordered the repair of the mixers around 2001 but later stated this order came in 2002. Amin claimed that the Iraqis used the one repaired mixer for about two months. Amin then convinced Huwaysh to allow him to destroy the mixer because it was a violation of UNSCR 687. According to Amin, this information was not disclosed to UNMOVIC.

- According to Huwaysh, in 2002 'Abd-al-Baqi Rashid Shia' Al Ta'i of the Al Rashid General Company was given permission to repair one of the two 300-gallon solid-propellant mixers. One of the mixers had been completely destroyed so 'Abd-al-Baqi restored the partially destroyed mixer.

A few sources have disclosed information about Iraq's efforts to rebuild the BADR-2000 aging oven, which was declared, destroyed by UNSCOM. An ISG site exploitation mission has confirmed these claims.

- An Iraqi scientist claimed that Iraq had rebuilt the aging oven associated with the BADR-2000 program at the Al Amin factory. He added that, since the maximum temperature in the furnace could not reach the required temperature of 1,000 degrees, the Iraqis built an even bigger furnace.

- An ISG site exploitation visit to Al Amin confirmed this claim, and ISG was able to inspect the restored BADR-2000 aging oven and a larger, built-in annealing furnace. ***ISG judges that both furnaces could be used in the production of motor cases with diameters larger than one meter, which is beyond the requirements for any rocket or missile permitted by the UN.***

In addition to the mixer and aging oven, ISG has identified two other areas where Iraq rebuilt or reused equipment that had been disabled, destroyed, or banned.

- According to a "certificate of machine repair" recovered by ISG, one of the three flow-forming machines at Al Karamah that had been destroyed by UNSCOM was rebuilt by February 2001. The document was signed by several department heads within the Al Samud program and included a statement that the machine's intended use was for the production of Al Samud rocket engine covers. ISG has been unable to locate this piece of equipment.

- Coalition forces recovered a letter from 'Abd-al-Baqi Rashid Shia', the director of the Al Rashid General Company, requesting a piece of steel one meter in diameter from a canceled project. The steel was a part of the Gerald Bull Supergun project, which Iraq was forced to terminate in order to comply with UNSCR 687. The letter from 'Abd-al-Baqi was in reference to the large diameter motor

project. Iraq attempted to use a barrel-section from the Supergun Project to create a prototype 1 meter diameter motor case but the effort failed because of material incompatibilities. Iraqi technicians were unable to weld the motor end domes to the Supergun barrel.

Iraq's restoration of prohibited equipment associated with past missile programs directly violated UN restrictions on Iraq's missile programs. Iraq chose to deliberately ignore these restrictions to improve its missile production infrastructure.

Undeclared Activities

Several former high-level Regime officials and scientists directly affiliated with Iraq's military industries have indicated that Iraq intentionally withheld information from the UN regarding its delivery systems programs, to include research into delivery systems with design ranges well in excess of 150 km.

- According to one former high-ranking government official, Huwaysh restricted the NMD's access to MIC when the NMD was preparing the 2002 CAFCD. As a result, some MIC work was omitted, which violated UNSCR 1441.

- Several sources have admitted their direct involvement in the destruction of documents related to delivery systems programs to prevent divulging them to the UN.

This pattern of activity occurred at all levels and indicates a widespread effort to protect certain activities and to deceive the international community. According to numerous sources, Iraq worked on several delivery system projects that were never declared to the UN, violating UNSCR 1441. Some of these projects were designed to achieve ranges beyond 150 km and if developed would have violated UNSCR 687 and 715. Many missile specialists directly involved in these projects have admitted to destroying documents related to these programs to prevent the UN from discovering them, which violates UNSCR 707.

- ***Through a series of interviews with former MIC and NMD officials, ISG has discovered that Iraq since 1991 did not disclose the IRFNA production capability at Al Qa'qa'a to the UN.*** One NMD official claimed that Husayn Kamil had passed an order not to declare this capability to the UN and this order was observed even after Husayn Kamil's death. Other officials claim that Iraq decided to withhold the IRFNA production capability of Al Qa'qa'a for fear that the UN would destroy the plant, virtually closing Iraq's extensive munitions industries.

- Former high-ranking MIC officials and scientists in the Iraqi missile program claim that, between 2000 and 2002, Huwaysh ordered Dr. Muzhir of Al Karamah to design a long-range liquid-propellant missile (see the Long-Range Missile chapter for more information). Huwaysh retained all the hard-copy evidence of this project and later destroyed it to prevent detection by the UN, although ISG has been able to uncover some design drawings for two long-range missile projects—the two- and five-engine clustered engine designs.

- An engineer associated with the Iraqi missile program claimed that, in early 2001, Huwaysh directed 'Abd-al-Baqi Rashid Shia' of the Al Rashid General Company to pursue a long-range solid-propellant missile. The engineer also provided a diagram for a launcher for a long-range solid-propellant missile, that Al Fida' engineers had been working on. The engineer claimed that research into this missile project ceased upon the arrival of UNMOVIC in late 2002 (see the Long-Range Missile chapter for more information).

- Much of Iraq's work on SA-2 conversion projects was never disclosed to the UN, according to officials associated with these projects. MIC officials decided to withhold all information from the UN about the Sa'd project, headed by Al Kindi, in part because it had not yet reached the prototype stage. Ra'ad Isma'il Jamil Al Adhami's SA-2 conversion efforts were not declared to the UN although the flight tests were manipulated so that the missiles would not exceed 150 km.

- Iraq withheld information about its efforts to extend the range of its HY-2 cruise missiles. Two individuals within MIC claimed that the 1,000 km Jinin cruise missile project ceased at the end of 2002 before the resumption of UNMOVIC inspections. One source said that the airframes were transferred from Al Karamah where the modifications

Graphite

Graphite is well known for its property of withstanding high temperatures and thermal shock, especially in nonoxidizing environments.

For missile applications, the denser it is, the more useful it is as a temperature-resistant material. Graphite densities below about 1,600 kg/m^3 (1.6 g/cc) are only useful for nonnuclear or nonrocket application. Densities above 1,700 kg/m^3 are useful for missiles and above 1,800 kg/m^3 for nuclear applications. Uses of high-density graphite include:

- *High-temperature crucibles.*
- *Anodes for electric steelmaking.*
- *Nuclear applications (graphite is a moderator).*
- *Missile and propulsion application.*

Missile applications include the nose tip, jet vanes, and nozzle throat inserts. High-density graphite is used in nose tips because it is temperature resistant and can withstand high dynamic pressure and thermal effects better than lower density graphite. High-density graphite can be used as a liner for the extreme thermal and erosive environment experienced in the throats of solid-propellant motor nozzles where the high temperature environment is made worse by the presence of alumina particles (from propellant combustion) in the exhaust. Graphite inserts are not commonly used in liquid-propellant engines.

High-density graphite is also used in thrust vector control vanes, where aerodynamic surfaces are used to deflect the exhaust gas flow path, thus changing the direction of thrust. Although this method incurs drag losses, it is effective in providing a control mechanism for missiles.

were being made to a storage warehouse before UNMOVIC arrived for fear of the project being discovered. Iraq's attempts to extend the range of the HY-2 anti-ship cruise missile to beyond 150 km in a land-attack role were not declared to the UN (see Cruise Missile chapter for more information).

- A few sources have admitted that at least one Iraqi UAV flew beyond 150 km, and Huwaysh claimed that Iraq had tested UAVs to a range of only 100 km but that the range could easily be increased to 500 km by adding a larger fuel tank. Huwaysh also suggested that the L-29 program was a 100% replacement for the MiG-21 RPV program, implying—but never directly saying—that the mission of the L-29 was to deliver CBW. ***ISG has no other evidence to support this statement*** (see the UAV section for more information).

- ***A high-level official within the Iraqi missile program claimed that, in an effort to make Iraq's missile infrastructure less dependent upon foreign suppliers, MIC directed university projects to research ingredients used in solid and liquid propellants***. ***Because of the sensitivity of this research, Iraq never disclosed these efforts to the UN.*** Former university students and individuals associated with the missile program alleged that this undisclosed research occurred at universities in Baghdad, Mosul, and Basra. Researchers claim their attempts to produce such materials, as Hydroxy Terminated Poly Butadiene (HTPB), Nitronium Perchlorate (NP), Nitroglycerine, and Hydrogen Peroxide at high concentration levels were unsuccessful.

ISG has exploited dozens of contracts that confirm the requests, orders, and deliveries of UN-restricted components and equipment involving facilities associated with Iraq's missile and UAV programs. Iraq's use of the Iraqi Intelligence Service, front companies, and false end user certificates indicate Iraq knew these activities violated international sanctions. Iraq also negotiated with other countries for complete missile systems, but there is no evidence any shipments were ever made (see the Procurement chapter for more information).

- Former high-level officials admit MIC procured ballistic missile engineering assistance, gyroscopes, SA-2/Volga missile engines, and SA-2 batteries from companies in Eastern Europe. ISG has recovered contracts and other documents to corroborate these admissions.

– Huwaysh admitted that Iraq had imported hundreds of SA-2/Volga liquid-propellant engines from companies in Poland—activities that were disclosed to UNMOVIC. ISG has exploited several official documents containing the contractual details (e.g., serial numbers of these engines).

- Former high-level MIC officials disclosed that Iraq received missile components such as gyroscopes and accelerometers from China.

- Huwaysh and an Iraqi scientist both asserted that Iraq received assistance and materials for missile propellants from Indian firms, particularly NEC.

- Several documents have been recovered that include information about Iraqi negotiations with North Korea for missile materials and long-range missile systems, probably including the 1,300-km-range No Dong. ***There is no evidence to confirm the delivery of any ballistic missile systems.***

- Statements from former high-level Regime officials and documentation indicate Russian entities provided assistance to Iraq's missile programs. Russian entities exported numerous key pieces of equipment to Iraq through illegal channels and also supplied technical experts. Iraq also negotiated for complete Iskander-E missiles systems, although no missiles were ever purchased or delivered, according to Huwaysh.

- Captured documents show Iraq's reliance on FRY assistance to develop a domestic G&C design, manufacture, calibration, and test capability. Iraq also imported guidance instruments from FRY.

- Former high-level MIC officials provided information about Iraq's procurement efforts through Ukraine. Iraq received missile and UAV components as well as technical assistance from the Ukraine.

Benefits of Carbon Fiber Filament Winding in Missile Construction

Carbon Fiber Filament Winding is ideal for missile construction because of the superior material properties of carbon fiber and the repeatability and consistency of the filament winding process.

Carbon fiber materials have superior material properties to glass fiber, aluminum, and steel in the areas of specific strength, specific stiffness, and relative density. Carbon fiber composites are five times stronger and five times lighter than 1020 steel with a specific strength (a combined measure of both strength and density) 13 times that of aluminum and 1.4 times that of glass fiber composites. The chart at the end of this section highlights the superior carbon fiber material properties.

The Iraqi missile and UAV programs benefited from Iraq's defiance of UN sanctions because they were able to obtain material and technical expertise they otherwise could not have developed. Several sources and documentary evidence confirm that Iraq participated in such activities. The measures taken to conceal these activities from the UN are evidence that Iraq was well aware these activities were illegal.

Role of the MTCR

Although Iraq is not a signatory of the Missile Technology Control Regime (MTCR)—a voluntary agreement among member states whose goal is to control missile proliferation—ISG uncovered substantial evidence that companies in MTCR member states provided missile components and technical assistance—some of these components and assistance may be controlled under the MTCR— to Iraq's delivery system programs.

- Sources within the Iraqi missile program disclosed that Iraq had contracts with Russia for flow-forming machines that may have been MTCR controlled, but ISG has been unable to confirm the delivery of such items. Computer numerically-controlled flow-forming machines with more than two axes, which can

be coordinated with simultaneously for contouring control—useful for making rocket motor cases, end domes and nozzles—are controlled under Category II of the MTCR annex.

- Individuals within MIC stated that Iraq received gyroscopes from Russia for use in their missile programs, specifically the Al Samud II. Contractual evidence also exists that corroborates source claims that Al Karamah imported gyroscopes from Russian companies. Coalition forces recovered gyroscopes with Cyrillic letters on them and documents in Russian at both Al Karamah and Al Milad, which suggests that these items were imported from Russia. Russia may have been in breech of the MTCR because gyroscopes, which measure rotation at about one or more axes, are Category II–controlled items if they have a drift rate of less than 0.5 degree per hour.
- ISG recovered a contract between a Russian entity and Iraq for Russian technical assistance for missile unidentified designs as well as Global Positioning System (GPS) equipment for unidentified missiles. GPS devices, if used to supplement or update the guidance set and increase the accuracy of a ballistic missile, are controlled under Category II of the MTCR annex.

A high-ranking official in the Iraqi missile program alleged that Iraq received AP and aluminum powder from a France firm via the Al 'Ayan Company. Iraq also received HTPB from an Italian firm via the Al Taqaddum Company, from a Japanese firm via the Al Sharqiyah Company and an unidentified source in the United States via the Indian firm NEC Engineers Private, Ltd. ***ISG has been unable to corroborate this information with any other source reporting or contracts.***

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Annex A
Resolving the Retained Scud-Variant Missile Question

Introduction

The data in this Annex are complementary to and in support of the material found in the Delivery Systems Report and as such should be referenced only in conjunction with that Report. Items in this Annex address specific topics that are presented in the Report but include greater detail or additional data, and provide more information to support the contentions and arguments in the main text.

1.1 Scud Missile Material Balance

Documentation recovered by ISG appears to be an Iraqi attempt to account for its Scud missiles. This material reportedly was never disclosed to the UN. The documentation includes the serial numbers for all 819 Scud missiles Iraq received from the Soviet Union between 1972 and 1988, contract numbers, and the disposition of these missiles broken down by serial number. Also included are two figures: the first entitled "Inventory Account of Used Rockets Provided by Russia (Declaration)" represents the Scud missile account as given to the UN; the second figure entitled "Inventory Account of Used Rockets Provided by Russia (Facts)" is, according to the engineer, the most accurate accounting for Iraq's Scud missiles. ***The numbers in this second figure vary from the numbers Iraq disclosed in its 2002 Currently Accurate Full, and Complete Declaration (CAFCD) to the UN, and the explanation for the discrepancy in the numbers is provided in these documents. According to the source of this information, these documents represent the full story on Scud missile material balance***. This material was most likely prepared to support a presentation at the Technical Evaluation Meetings (TEMs) held in Baghdad in early 1998.

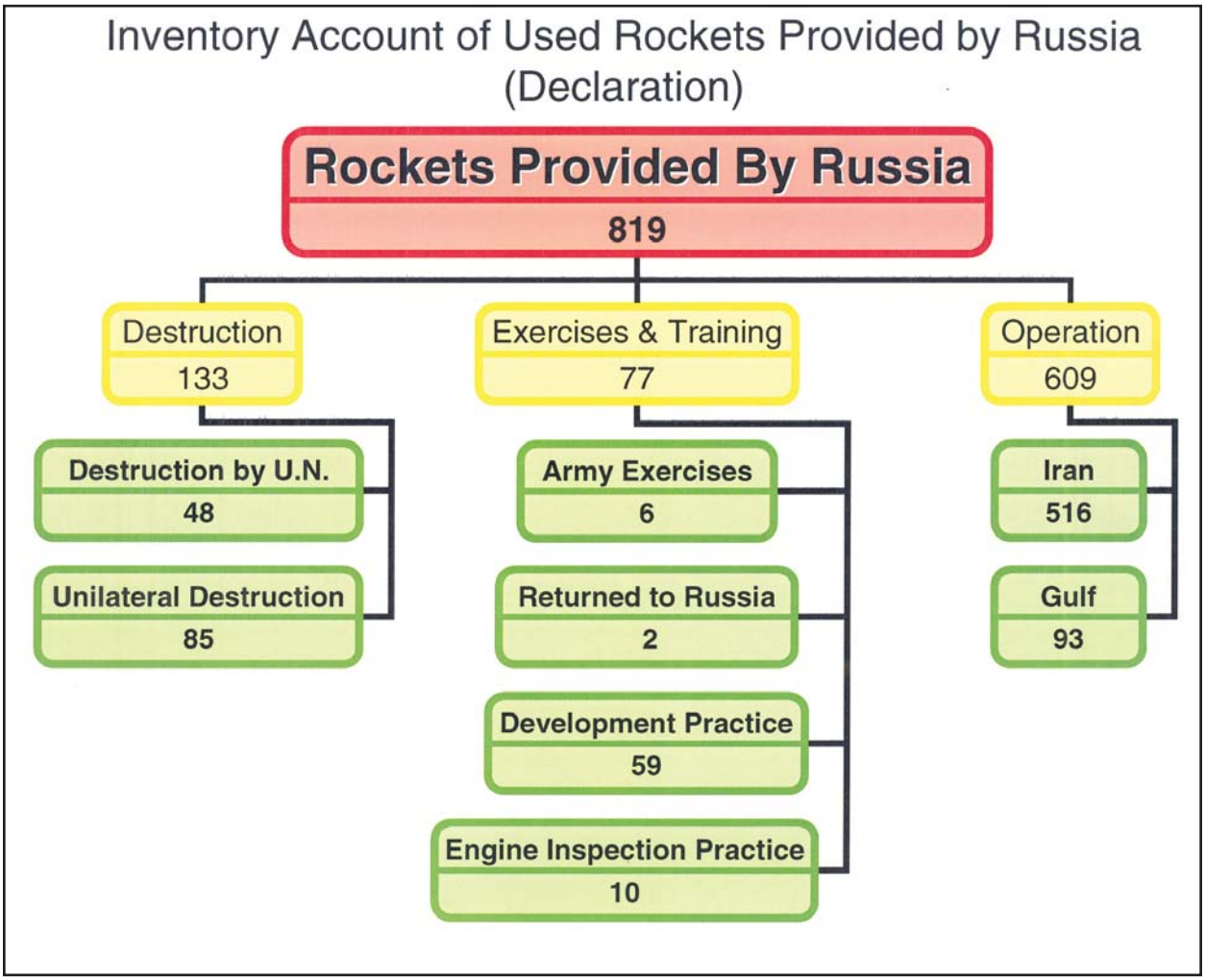

Figure 1. *Inventory account of used rockets provided by Russia (declaration).*

Available data suggest that Iraq's declaration of its unilateral destruction to the UN was assembled from eyewitness accounts rather than by matching up serial numbers. The Regime officials who participated in this effort supposedly interviewed more than 100 army personnel and other individuals who saw or claimed to have seen the disposition of the Scud missiles at some time. The method in which this information was derived was susceptible to error and, as such, should likely not have been forwarded to the UN as the official position.

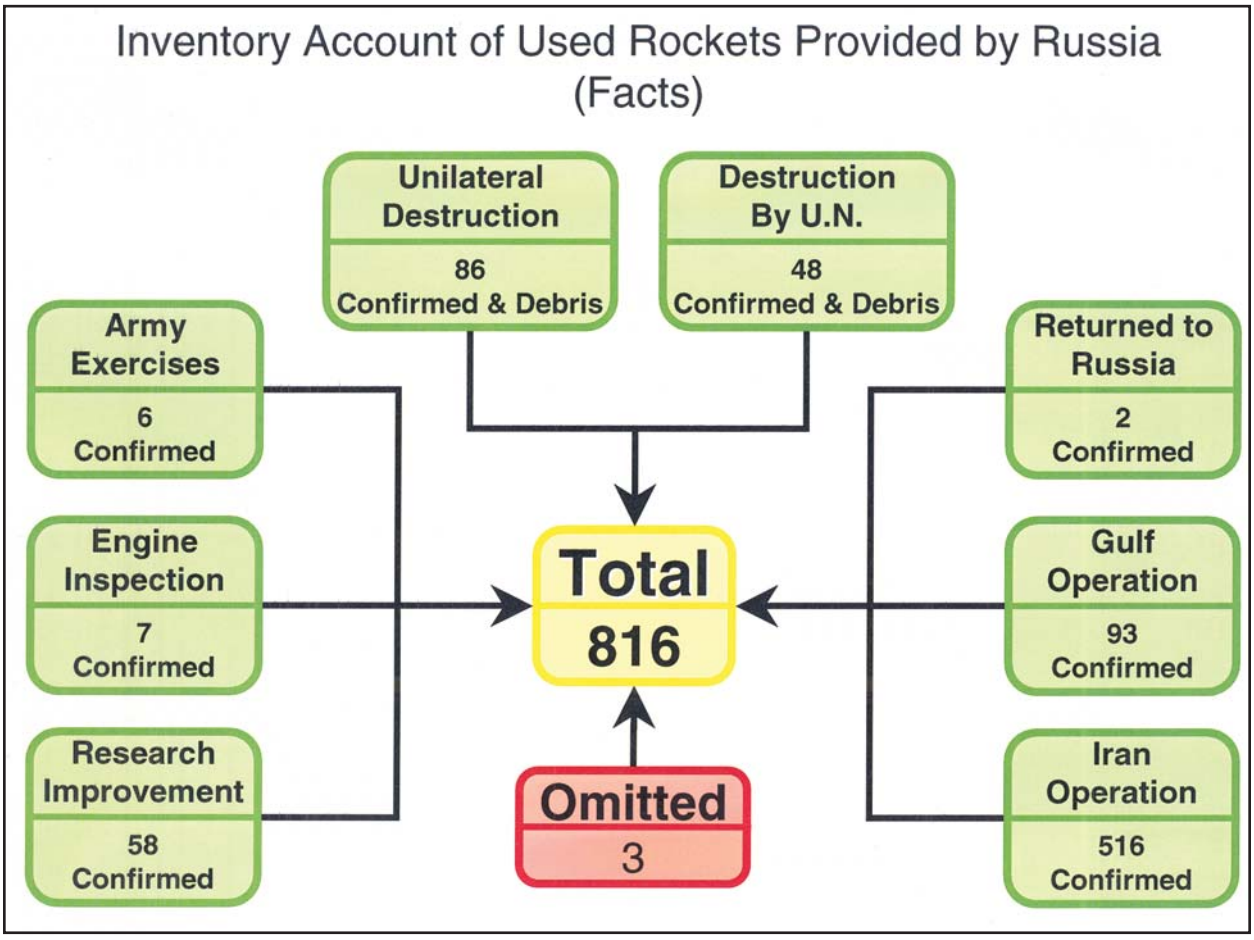

Figure 2. *Inventory account of used rockets provided by Russia (facts).*

Figure 2 reportedly contains Iraq's most accurate accounting for its Scud missiles. The figures in the chart are supported by the serial numbers contained in some of the other documents. The total number of missiles listed in the accounting is 816 vice 819, and an explanation was attempted, shown in the following inset.

The 3 Missing Scud Missiles

ISG derived the following information from recovered documents. This explanation was part of the overall effort to provide the most accurate accounting for Scud missiles, which the UN has reportedly not seen.

- ***Engine for Missile Serial Number 853667.*** *Engine serial number 85366, was used to replace engine 878426 in a flight test on 28 December 1990. According to the source's diary, remnants of engine 878426 appeared in debris of Iraq's unilaterally destroyed missiles, and tests of these remnants indicated that the engine had never been fired. Engine 878426 had been given to Project 144/2 for use in an Al Husayn, but, confusingly, the diary records that the engine was also used in the December test. 878426 had in fact been unilaterally destroyed, which is why forensic tests of the remnants showed that the engine had never been fired.*

- ***Engine for Missile Serial Number 853648.*** *The warhead for the engine with serial number 853648 appeared under serial number 8507101 in 1992 as part of the unilaterally destroyed debris, but, when the debris was rechecked in 1996, they were unable to locate this item again and was therefore considered unaccounted for.*

- ***Engine for Missile Serial Number 866417.*** *In 1992 among the remnants of the unilaterally destroyed material, a nozzle was encountered, which had an illegible serial number. The number read 8-2-16. The number was thought to be 852016 or 8552216; however, missiles with these serial numbers were never delivered to Iraq. As with the previous engine, this nozzle was not found among the debris when it was rechecked in 1996. A document recovered from Project 144/2 noted that engine 866417 was present for modification for the Al Husayn.*

ISG assesses that the accounting for missiles 853648 and 866417 is still incomplete.

Below is the breakdown for all 819 SCUD-B missiles according to the year of delivery and serial number. This information is reflected in Figure 2.

Year of Delivery-1974		
1	742504	Training
2	742509	Iran-Iraq War
3	742516	Iran-Iraq War
4	742519	Iran-Iraq War
5	742524	Training
6	742527	Iran-Iraq War
7	742530	Iran-Iraq War
8	742532	Iran-Iraq War
9	742536	Iran-Iraq War
10	742540	Iran-Iraq War
11	742543	Training
12	742547	Iran-Iraq War
13	742552	Iran-Iraq War
14	742559	Iran-Iraq War
15	742562	Iran-Iraq War
16	742565	Iran-Iraq War
17	742568	Training
18	742570	Iran-Iraq War
19	742571	Iran-Iraq War
20	742577	Training
21	742581	Training
22	742587	Iran-Iraq War
23	742591	Iran-Iraq War
24	742595	Iran-Iraq War
25	742598	Iran-Iraq War
26	742602	Iran-Iraq War
27	742606	Iran-Iraq War
28	742614	Iran-Iraq War
29	742618	Iran-Iraq War
30	742620	Iran-Iraq War
31	742626	Iran-Iraq War
32	742629	Iran-Iraq War
33	742634	Iran-Iraq War
34	742638	Iran-Iraq War
35	742645	Iran-Iraq War
36	742650	Returned
37	742655	Iran-Iraq War
38	742657	Iran-Iraq War
39	742673	Iran-Iraq War
40	742675	Iran-Iraq War
41	742679	Iran-Iraq War
42	742684	Iran-Iraq War
43	742689	Iran-Iraq War
44	742693	Returned
45	742699	Iran-Iraq War

Year of Delivery-1978		
46	784018	Iran-Iraq War
47	784020	Iran-Iraq War
48	784023	Iran-Iraq War
49	784026	Iran-Iraq War
50	784029	Iran-Iraq War
51	784031	Iran-Iraq War
52	784034	Iran-Iraq War
53	784037	Iran-Iraq War
54	784040	Iran-Iraq War
55	784045	Iran-Iraq War
56	784048	Iran-Iraq War
57	784053	Iran-Iraq War
58	784056	Iran-Iraq War
59	784059	Iran-Iraq War
60	784064	Iran-Iraq War
61	784067	Iran-Iraq War
62	784093	Iran-Iraq War
63	784103	Iran-Iraq War
64	784106	Iran-Iraq War
65	784110	Iran-Iraq War
66	784111	Iran-Iraq War
67	784113	Iran-Iraq War
68	784117	Iran-Iraq War
69	784119	Iran-Iraq War
70	784121	Iran-Iraq War
71	784124	Iran-Iraq War
72	784127	Iran-Iraq War
73	784130	Iran-Iraq War
74	784133	Iran-Iraq War
75	784136	Iran-Iraq War
76	784139	Iran-Iraq War
77	784142	Iran-Iraq War
78	784144	Iran-Iraq War
79	784147	Iran-Iraq War
80	784150	Iran-Iraq War
81	784155	Iran-Iraq War

82	784158	Iran-Iraq War
83	784161	Iran-Iraq War
84	784166	Iran-Iraq War
85	784169	Iran-Iraq War
86	784174	Iran-Iraq War
87	784180	Iran-Iraq War

Year of Delivery-1979		
88	794532	Iran-Iraq War
89	794535	Iran-Iraq War
90	794537	Iran-Iraq War
91	794539	Iran-Iraq War
92	794541	Iran-Iraq War
93	794544	Iran-Iraq War
94	794548	Iran-Iraq War
95	794551	Iran-Iraq War
96	794556	Iran-Iraq War
97	794559	Iran-Iraq War
98	794564	Iran-Iraq War
99	794569	Iran-Iraq War
100	794573	Iran-Iraq War
101	794576	Iran-Iraq War
102	794578	Iran-Iraq War
103	794581	Iran-Iraq War
104	794590	Iran-Iraq War
105	794592	Iran-Iraq War
106	794599	Iran-Iraq War
107	794602	Iran-Iraq War
108	794612	Iran-Iraq War
109	794614	Iran-Iraq War
110	794617	Iran-Iraq War
111	794621	Iran-Iraq War
112	794624	Iran-Iraq War
113	794628	Iran-Iraq War
114	794634	Iran-Iraq War
115	794636	Iran-Iraq War

Year of Delivery-1982		
116	827615	Iran-Iraq War
117	827618	Iran-Iraq War
118	827621	Iran-Iraq War
119	827624	Iran-Iraq War
120	827627	Iran-Iraq War
121	827632	Iran-Iraq War
122	827637	Iran-Iraq War
123	827640	Iran-Iraq War
124	827643	Iran-Iraq War
125	827645	Iran-Iraq War
126	827648	Iran-Iraq War
127	827653	Iran-Iraq War
128	827656	Iran-Iraq War
129	827660	Iran-Iraq War
130	827663	Iran-Iraq War
131	827668	Iran-Iraq War
132	827671	Iran-Iraq War
133	827676	Iran-Iraq War
134	827679	Iran-Iraq War
135	827682	Iran-Iraq War
136	827684	Iran-Iraq War
137	827688	Iran-Iraq War
138	827691	Iran-Iraq War
139	827694	Iran-Iraq War
140	827697	Iran-Iraq War
141	827702	Iran-Iraq War
142	827703	Iran-Iraq War
143	827705	Iran-Iraq War
144	827706	Iran-Iraq War
145	827708	Iran-Iraq War

Year of Delivery-1983		
146	838648	Iran-Iraq War
147	838650	Iran-Iraq War
148	838653	Iran-Iraq War
149	838656	Iran-Iraq War
150	838658	Iran-Iraq War
151	838661	Iran-Iraq War
152	838664	Iran-Iraq War
153	838666	Iran-Iraq War
154	838669	Iran-Iraq War
155	838671	Iran-Iraq War
156	838673	Iran-Iraq War
157	838676	Iran-Iraq War
158	838679	Iran-Iraq War
159	838682	Iran-Iraq War
160	838686	Iran-Iraq War
161	838693	Iran-Iraq War
162	838695	Iran-Iraq War
163	838706	Iran-Iraq War

164	838710	Iran-Iraq War
165	838713	Iran-Iraq War
166	838716	Iran-Iraq War
167	838721	Iran-Iraq War
168	838724	Iran-Iraq War
169	838730	Iran-Iraq War
170	838733	Iran-Iraq War
171	838993	Iran-Iraq War
172	838996	Iran-Iraq War
173	838997	Iran-Iraq War
174	838999	Iran-Iraq War
175	839021	Iran-Iraq War
176	839024	Iran-Iraq War
177	839027	Iran-Iraq War
178	839033	Iran-Iraq War
179	839036	Iran-Iraq War
180	839039	Iran-Iraq War
181	839042	Iran-Iraq War
182	839045	Iran-Iraq War
183	839048	Iran-Iraq War
184	839051	Iran-Iraq War
185	839054	Iran-Iraq War
186	839057	Iran-Iraq War
187	839060	Iran-Iraq War
188	839065	Iran-Iraq War
189	839068	Iran-Iraq War
190	839073	Iran-Iraq War

Year of Delivery-1984		
191	841101	Iran-Iraq War
192	841104	Iran-Iraq War
193	841107	Iran-Iraq War
194	841110	Iran-Iraq War
195	841112	Iran-Iraq War
196	841118	Iran-Iraq War
197	841123	Iran-Iraq War
198	841126	Iran-Iraq War
199	841129	Iran-Iraq War
200	841131	Iran-Iraq War
201	841134	Iran-Iraq War
202	841137	Iran-Iraq War
203	841140	Iran-Iraq War
204	841143	Iran-Iraq War
205	841146	Iran-Iraq War
206	841149	Iran-Iraq War
207	841152	Iran-Iraq War
208	841155	Iran-Iraq War
209	841158	Iran-Iraq War
210	841161	Iran-Iraq War
211	841164	Iran-Iraq War
212	841166	Iran-Iraq War
213	841169	Iran-Iraq War
214	841202	Iran-Iraq War
215	841214	Iran-Iraq War
216	841220	Iran-Iraq War
217	841225	Iran-Iraq War
218	841228	Iran-Iraq War
219	841233	Iran-Iraq War
220	841238	Iran-Iraq War
221	841245	Iran-Iraq War
222	841250	Iran-Iraq War
223	841253	Iran-Iraq War
224	841342	Iran-Iraq War
225	831347	Iran-Iraq War
226	841354	Iran-Iraq War
227	841357	Iran-Iraq War
228	841360	Iran-Iraq War
229	841363	Iran-Iraq War
230	841370	Iran-Iraq War
231	841373	Iran-Iraq War
232	841376	Iran-Iraq War
233	841379	Iran-Iraq War
234	841384	Iran-Iraq War
235	841388	Iran-Iraq War
236	841389	Iran-Iraq War
237	841392	Iran-Iraq War
238	841394	Iran-Iraq War
239	841395	Iran-Iraq War
240	841398	Iran-Iraq War
241	841414	Iran-Iraq War
242	841417	Iran-Iraq War
243	841420	Iran-Iraq War
244	841423	Iran-Iraq War
245	841426	Iran-Iraq War
246	841429	Iran-Iraq War
247	841432	Iran-Iraq War
248	841435	Iran-Iraq War
249	841438	Iran-Iraq War
250	841441	Iran-Iraq War
251	841444	Iran-Iraq War

252	841447	Iran-Iraq War
253	841450	Iran-Iraq War
254	841453	Iran-Iraq War
255	841456	Iran-Iraq War
256	841459	Iran-Iraq War
257	841462	Iran-Iraq War
258	841465	Iran-Iraq War
259	841468	Iran-Iraq War
260	841471	Iran-Iraq War
261	841474	Iran-Iraq War
262	841477	Iran-Iraq War
263	841482	Iran-Iraq War
264	841485	Iran-Iraq War
265	841489	Iran-Iraq War
266	841494	Iran-Iraq War
267	841592	Iran-Iraq War
268	841598	Iran-Iraq War
269	841602	Iran-Iraq War
270	841605	Iran-Iraq War
271	841608	Iran-Iraq War
272	841616	Iran-Iraq War
273	841621	Iran-Iraq War
274	841624	Test for dev. missile
275	841630	Iran-Iraq War
276	841636	Iran-Iraq War
277	841642	Iran-Iraq War
278	841645	Iran-Iraq War
279	841648	Iran-Iraq War
280	841651	Iran-Iraq War
281	841654	Iran-Iraq War
282	841658	Iran-Iraq War
283	841661	Iran-Iraq War
284	841666	Iran-Iraq War
285	841669	Iran-Iraq War
286	841672	Iran-Iraq War
287	841683	Iran-Iraq War
288	841686	Iran-Iraq War
289	841691	Iran-Iraq War
290	841693	Iran-Iraq War
291	841854	Iran-Iraq War
292	841857	Iran-Iraq War
293	841860	Iran-Iraq War
294	841862	Iran-Iraq War
295	841865	Iran-Iraq War
296	841870	Iran-Iraq War
297	841877	Test for dev. missile
298	841888	Iran-Iraq War
299	841891	Iran-Iraq War
300	841896	Iran-Iraq War
301	841899	Iran-Iraq War
302	841901	Iran-Iraq War
303	841911	Iran-Iraq War
304	841916	Iran-Iraq War
305	841919	Iran-Iraq War
306	841922	Iran-Iraq War
307	841925	Iran-Iraq War
308	841928	Iran-Iraq War
309	841931	Iran-Iraq War
310	841935	Iran-Iraq War
311	841942	Iran-Iraq War
312	841945	Iran-Iraq War
313	841949	Iran-Iraq War
314	841952	Iran-Iraq War
315	841959	Iran-Iraq War
316	841964	Iran-Iraq War
317	841967	Iran-Iraq War
318	841972	Iran-Iraq War
319	841978	Iran-Iraq War
320	841983	Iran-Iraq War
321	841986	Iran-Iraq War
322	841989	Iran-Iraq War
323	841992	Iran-Iraq War
324	841995	Iran-Iraq War
325	841998	Iran-Iraq War

Year of Delivery-1985		
326	853203	Iran-Iraq War
327	853208	Test for dev. missile
328	853215	Unilaterally destroyed
329	853222	UNSCOM destroyed
330	853225	Iran-Iraq War
331	853233	Iran-Iraq War
332	853238	UNSCOM destroyed
333	853242	Iran-Iraq War
334	853249	Iran-Iraq War
335	853252	Iran-Iraq War
336	853255	Iran-Iraq War
337	853259	Desert Storm
338	853261	Iran-Iraq War

339	853265	Iran-Iraq War
340	853268	Test for dev. missile
341	853271	Unilaterally destroyed
342	853272	Iran-Iraq War
343	853275	Desert Storm
344	853341	UNSCOM destroyed
345	853344	Desert Storm
346	853347	Iran-Iraq War
347	853350	UNSCOM destroyed
348	853354	UNSCOM destroyed
349	853357	UNSCOM destroyed
350	853363	Desert Storm
351	853367	Unilaterally destroyed
352	853370	Iran-Iraq War
353	853374	Desert Storm
354	853379	Iran-Iraq War
355	853382	UNSCOM destroyed
356	853387	Test for dev. missile
357	853390	Desert Storm
358	853392	Desert Storm
359	853399	Unilaterally destroyed
360	853402	Iran-Iraq War
361	853405	Iran-Iraq War
362	853409	Test for dev. missile
363	853411	Iran-Iraq War
364	853413	Iran-Iraq War
365	853417	Test for dev. missile
366	853421	Test for dev. missile
367	853423	Iran-Iraq War
368	853426	UNSCOM destroyed
369	853428	Iran-Iraq War
370	853434	Test for dev. missile
371	853440	Iran-Iraq War
372	853443	Iran-Iraq War
373	853446	Test for dev. missile
374	853448	Iran-Iraq War
375	853449	UNSCOM destroyed
376	853451	Test for dev. missile
377	853453	Iran-Iraq War
378	853458	Iran-Iraq War
379	853462	Test for dev. missile
380	853469	Unilaterally destroyed
381	853473	Iran-Iraq War
382	853478	Unilaterally destroyed
383	853481	Iran-Iraq War

384	853484	UNSCOM destroyed
385	853489	Iran-Iraq War
386	853491	Test for dev. missile
387	853494	Engine test
388	853497	Unilaterally destroyed
389	853501	Unilaterally destroyed
390	853503	Desert Storm
391	853507	Desert Storm
392	853510	Desert Storm
393	853512	Test for dev. missile
394	853514	Desert Storm
395	853518	Unilaterally destroyed
396	853520	Unilaterally destroyed
397	853523	Desert Storm
398	853525	Desert Storm
399	853528	Unilaterally destroyed
400	853530	Unilaterally destroyed
401	853534	Unilaterally destroyed
402	853538	Unilaterally destroyed
403	853541	Test for dev. missile
404	853546	Unilaterally destroyed
405	853553	Desert Storm
406	853557	UNSCOM destroyed
407	853561	UNSCOM destroyed
408	853565	Desert Storm
409	853573	Unilaterally destroyed
410	853575	Test for dev. missile
411	853581	UNSCOM destroyed
412	853587	Unilaterally destroyed
413	853591	Unilaterally destroyed
414	853595	Unilaterally destroyed
415	853596	Unilaterally destroyed
416	853598	Desert Storm
417	853602	Desert Storm
418	853604	Test for dev. missile
419	853606	Unilaterally destroyed
420	853608	Desert Storm
421	853611	Test for dev. missile
422	853613	Unilaterally destroyed
423	853616	Test for dev. missile
424	853622	Desert Storm
425	853626	Unilaterally destroyed
426	853633	Unilaterally destroyed
427	853636	Test for dev. missile
428	853640	Unilaterally destroyed

429	853643	UNSCOM destroyed
430	853645	Desert Storm
431	853648	**See insert
432	853651	Unilaterally destroyed
433	853655	Desert Storm
434	853659	Unilaterally destroyed
435	853663	Desert Storm
436	853667	**See insert
437	853676	Unilaterally destroyed
438	853679	Desert Storm
439	853683	Unilaterally destroyed
440	853685	UNSCOM destroyed
441	853689	Unilaterally destroyed

Year of Delivery-1986		
442	863692	Iran-Iraq War
443	863694	Unilaterally destroyed
444	863697	Iran-Iraq War
445	863699	Iran-Iraq War
446	863701	Iran-Iraq War
447	863702	Iran-Iraq War
448	863703	Iran-Iraq War
449	863707	Test for dev. missile
450	863708	Unilaterally destroyed
451	863710	Iran-Iraq War
452	863711	Iran-Iraq War
453	863715	Iran-Iraq War
454	863716	Iran-Iraq War
455	863719	Iran-Iraq War
456	863721	Iran-Iraq War
457	863723	Iran-Iraq War
458	863724	Iran-Iraq War
459	863726	Iran-Iraq War
460	863729	UNSCOM destroyed
461	863730	Iran-Iraq War
462	863736	Iran-Iraq War
463	863739	Iran-Iraq War
464	863743	Iran-Iraq War
465	863751	Iran-Iraq War
466	863752	Iran-Iraq War
467	863755	Unilaterally destroyed
468	863756	Iran-Iraq War
469	863762	Iran-Iraq War
470	863764	Iran-Iraq War
471	863772	Iran-Iraq War
472	863778	Iran-Iraq War
473	863780	Unilaterally destroyed
474	866131	Unilaterally destroyed
475	866134	Iran-Iraq War
476	866137	Iran-Iraq War
477	866139	Iran-Iraq War
478	866140	Iran-Iraq War
479	866141	Iran-Iraq War
480	866146	Iran-Iraq War
481	866149	Iran-Iraq War
482	866151	Test for dev. missile
483	866156	Iran-Iraq War
484	866158	Iran-Iraq War
485	866161	Iran-Iraq War
486	866163	Desert Storm
487	866169	Iran-Iraq War
488	866175	Iran-Iraq War
489	866187	Iran-Iraq War
490	866193	Iran-Iraq War
491	866197	Iran-Iraq War
492	866203	Iran-Iraq War
493	866205	Iran-Iraq War
494	866209	Test for dev. missile
495	866212	Test for dev. missile
496	866215	Desert Storm
497	866217	Iran-Iraq War
498	866219	Unilaterally destroyed
499	866221	Iran-Iraq War
500	866224	Iran-Iraq War
501	866227	Unilaterally destroyed
502	866229	Iran-Iraq War
503	866231	UNSCOM destroyed
504	866232	Test for dev. missile
505	866235	Test for dev. missile
506	866237	Iran-Iraq War
507	866242	Unilaterally destroyed
508	866247	Iran-Iraq War
509	866250	Iran-Iraq War
510	866252	Iran-Iraq War
511	866256	Unilaterally destroyed
512	866260	Iran-Iraq War
513	866264	Iran-Iraq War
514	866269	Iran-Iraq War
515	866270	Unilaterally destroyed
516	866274	Iran-Iraq War

517	866277	Unilaterally destroyed
518	866280	Iran-Iraq War
519	866288	Iran-Iraq War
520	866293	Iran-Iraq War
521	866302	Iran-Iraq War
522	866304	UNSCOM destroyed
523	866309	Iran-Iraq War
524	866311	Iran-Iraq War
525	866313	Iran-Iraq War
526	866314	Test for dev. missile
527	866318	Iran-Iraq War
528	866320	Iran-Iraq War
529	866322	Iran-Iraq War
530	866325	Iran-Iraq War
531	866328	Desert Storm
532	866331	Iran-Iraq War
533	866333	Iran-Iraq War
534	866337	Iran-Iraq War
535	866340	Iran-Iraq War
536	866341	Iran-Iraq War
537	866345	Test for dev. missile
538	866348	UNSCOM destroyed
539	866353	Desert Storm
540	866357	Desert Storm
541	866359	Desert Storm
542	866363	Desert Storm
543	866366	UNSCOM destroyed
544	866368	Desert Storm
545	866373	Unilaterally destroyed
546	866405	UNSCOM destroyed
547	866406	Desert Storm
548	866412	Iran-Iraq War
549	866417	**See insert
550	866423	Unilaterally destroyed
551	866427	Desert Storm
552	866432	UNSCOM destroyed
553	866434	Iran-Iraq War
554	866442	Iran-Iraq War
555	866444	Iran-Iraq War
556	866449	Unilaterally destroyed
557	866454	Desert Storm
558	866458	Iran-Iraq War
559	866460	UNSCOM destroyed
560	866467	Unilaterally destroyed
561	866469	Iran-Iraq War

562	866470	UNSCOM destroyed
563	866471	Unilaterally destroyed
564	866474	Unilaterally destroyed
565	866476	Iran-Iraq War
566	866477	Unilaterally destroyed
567	866481	Iran-Iraq War
568	866484	UNSCOM destroyed
569	866487	Desert Storm
570	866490	Desert Storm
571	866504	Desert Storm
572	866507	Engine test
573	866508	Unilaterally destroyed
574	866513	Test for dev. missile
575	866516	Desert Storm
576	866519	Desert Storm
577	866524	Test for dev. missile
578	866527	Unilaterally destroyed
579	866530	Desert Storm
580	866533	Desert Storm
581	866535	Desert Storm
582	866539	Desert Storm
583	866543	Unilaterally destroyed
584	866544	Desert Storm
585	866547	Unilaterally destroyed
586	866550	Desert Storm
587	866552	Unilaterally destroyed
588	866557	Test for dev. missile
589	866564	Unilaterally destroyed
590	866570	Unilaterally destroyed
591	866573	UNSCOM destroyed
592	866585	Test for dev. missile
593	866590	Desert Storm
594	866593	Test for dev. missile
595	866595	Iran-Iraq War
596	866597	Desert Storm
597	866598	Iran-Iraq War
598	866599	Test for dev. missile
599	866602	Desert Storm
600	866605	Unilaterally destroyed
601	866614	UNSCOM destroyed
602	866620	Test for dev. missile
603	866628	UNSCOM destroyed
604	866634	Iran-Iraq War
605	866641	Test for dev. missile
606	866649	Desert Storm

607	866654	Iran-Iraq War
608	866658	Desert Storm
609	866664	Desert Storm
610	866667	UNSCOM destroyed
611	866669	UNSCOM destroyed
612	866674	UNSCOM destroyed
613	866677	Iran-Iraq War
614	866679	Desert Storm
615	866682	Desert Storm
616	866684	Desert Storm
617	866686	Iran-Iraq War
618	866688	Iran-Iraq War
619	866689	Desert Storm
620	866691	UNSCOM destroyed
621	866692	Desert Storm
622	866693	Desert Storm
623	866694	Unilaterally destroyed
624	866695	Unilaterally destroyed
625	866697	Unilaterally destroyed
626	866698	Desert Storm

Year of Delivery-1987		
627	876704	Unilaterally destroyed
628	876711	Unilaterally destroyed
629	876716	Desert Storm
630	876723	UNSCOM destroyed
631	876726	Unilaterally destroyed
632	876734	Desert Storm
633	876739	Desert Storm
634	876743	UNSCOM destroyed
635	876746	Desert Storm
636	876754	Desert Storm
637	876758	Test for dev. missile
638	876762	Unilaterally destroyed
639	876766	Engine test
640	876768	Desert Storm
641	876771	Unilaterally destroyed
642	876773	Desert Storm
643	876776	UNSCOM destroyed
644	876778	Desert Storm
645	876782	Engine test
646	876784	Desert Storm
647	876786	UNSCOM destroyed
648	876789	Unilaterally destroyed
649	876790	Unilaterally destroyed
650	876792	Test for dev. missile
651	876794	Desert Storm
652	876795	Test for dev. missile
653	876797	Engine test
654	876798	Desert Storm
655	876799	Test for dev. missile
656	878303	Test for dev. missile
657	878306	UNSCOM destroyed
658	878312	Test for dev. missile
659	878315	Desert Storm
660	878318	Desert Storm
661	878321	Test for dev. missile
662	878324	Unilaterally destroyed
663	878327	Test for dev. missile
664	878329	Test for dev. missile
665	878333	Test for dev. missile
666	878336	UNSCOM destroyed
667	878338	Unilaterally destroyed
668	878341	Desert Storm
669	878343	Desert Storm
670	878346	Test for dev. missile
671	878349	UNSCOM destroyed
672	878351	UNSCOM destroyed
673	878354	UNSCOM destroyed
674	878357	Test for dev. missile
675	878361	Desert Storm
676	878363	Unilaterally destroyed
677	878368	Test for dev. missile
678	878371	UNSCOM destroyed
679	878374	Desert Storm
680	878379	Desert Storm
681	878382	Unilaterally destroyed
682	878386	Desert Storm
683	878392	Desert Storm
684	878396	Test for dev. missile
685	878401	Desert Storm
686	878405	Desert Storm
687	878409	Test for dev. missile
688	878414	Unilaterally destroyed
689	878416	Test for dev. missile
690	878419	Desert Storm
691	878423	Desert Storm
692	878426	Unilaterally destroyed
693	878430	Unilaterally destroyed
694	878434	Test for dev. missile

695	878435	Desert Storm
696	878439	Desert Storm
697	878442	Test for dev. missile
698	878445	Engine test
699	878453	Unilaterally destroyed
700	878456	Unilaterally destroyed
701	878463	Desert Storm
702	878466	Iran-Iraq War
703	878470	Iran-Iraq War
704	878473	Iran-Iraq War
705	878476	Iran-Iraq War
706	878484	Unilaterally destroyed
707	878485	Iran-Iraq War
708	878488	Iran-Iraq War
709	878491	Iran-Iraq War
710	878494	Iran-Iraq War
711	878497	Iran-Iraq War
712	878499	Iran-Iraq War
713	878502	Iran-Iraq War
714	878504	Iran-Iraq War
715	878507	Iran-Iraq War
716	878511	Iran-Iraq War
717	878513	Unilaterally destroyed
718	878517	Iran-Iraq War
719	878520	Iran-Iraq War
720	878528	Iran-Iraq War
721	878531	Iran-Iraq War
722	878537	Iran-Iraq War
723	878544	Unilaterally destroyed
724	878547	Iran-Iraq War
725	878552	Iran-Iraq War
726	878559	Iran-Iraq War
727	878562	Iran-Iraq War
728	878567	Iran-Iraq War
729	878569	Iran-Iraq War
730	878572	UNSCOM destroyed
731	878575	Iran-Iraq War
732	878577	Iran-Iraq War
733	878581	Iran-Iraq War
734	878583	Test for dev. missile
735	878589	Iran-Iraq War
736	878590	Iran-Iraq War
737	878593	Iran-Iraq War
738	878595	Iran-Iraq War
739	878596	Iran-Iraq War

740	878597	Iran-Iraq War
741	878599	Iran-Iraq War
742	878601	Iran-Iraq War
743	878608	Iran-Iraq War
744	878610	Iran-Iraq War
745	878615	Iran-Iraq War
746	878619	Iran-Iraq War
747	878622	Iran-Iraq War
748	878625	Iran-Iraq War
749	878627	Iran-Iraq War
750	878629	Iran-Iraq War
751	878632	Iran-Iraq War
752	878635	Unilaterally destroyed
753	878640	Iran-Iraq War
754	878642	Iran-Iraq War
755	878648	Iran-Iraq War
756	878651	Iran-Iraq War
757	878653	Iran-Iraq War
758	878656	Iran-Iraq War
759	878658	UNSCOM destroyed
760	878660	Test for dev. missile
761	878663	Iran-Iraq War
762	878666	Iran-Iraq War
763	878671	Iran-Iraq War
764	878673	Iran-Iraq War
765	878678	Unilaterally destroyed
766	878682	Iran-Iraq War
767	878685	Iran-Iraq War
768	878687	Test for dev. missile
769	878691	Desert Storm
770	878694	Test for dev. missile
771	878696	Desert Storm
772	878704	Iran-Iraq War
773	878707	Iran-Iraq War
774	878711	Iran-Iraq War
775	878716	Iran-Iraq War
776	878720	Iran-Iraq War
777	878723	Iran-Iraq War
778	878726	Iran-Iraq War
779	878731	Iran-Iraq War
780	878734	Iran-Iraq War
781	878737	Unilaterally destroyed
782	878739	Engine test
783	878744	Unilaterally destroyed
784	878747	Unilaterally destroyed

785	878750	Unilaterally destroyed
786	878752	Iran-Iraq War
787	878755	Unilaterally destroyed
788	878759	Iran-Iraq War
789	878762	Unilaterally destroyed
790	878764	UNSCOM destroyed
791	878767	Iran-Iraq War
792	878770	UNSCOM destroyed
793	878772	UNSCOM destroyed
794	878775	UNSCOM destroyed
795	878779	Iran-Iraq War
796	878809	Iran-Iraq War
797	878811	Iran-Iraq War
798	878817	Iran-Iraq War
799	878822	Desert Storm
800	878825	Iran-Iraq War
801	878829	Iran-Iraq War
802	878833	Iran-Iraq War
803	878836	Iran-Iraq War
804	878840	Iran-Iraq War
805	878845	Desert Storm
806	878850	Iran-Iraq War
807	878858	Iran-Iraq War
808	878861	Iran-Iraq War
809	878866	Desert Storm
810	878869	Desert Storm
811	878873	Desert Storm
812	878877	Iran-Iraq War
813	878878	Iran-Iraq War
814	878880	Iran-Iraq War
815	878883	Desert Storm
816	878886	Iran-Iraq War
817	878887	Iran-Iraq War
818	878890	Iran-Iraq War
819	878891	Iran-Iraq War

1.2 Scud Warhead Material Balance

ISG has collected an official National Monitoring Directorate (NMD) document, dated 12 December 1997, on the expenditure of Scud warheads imported from the Soviet Union, which differs from the figures provided in the 1996 Full, Final, and Complete Disclosure (FFCD). These FFCD data are also repeated in the 2002 CAFCD. The NMD document is most likely part of that organization's effort to reconcile the material for imported Scud warheads. Although unable to verify information, ISG judges that this is a factual accounting for the 819 Scud warheads Iraq imported from the Soviet Union.

As with the data in for missile consumption (Section 1.1), this material was most likely prepared to support a presentation at the Warhead Technical Evaluation Meeting (TEM) held in Baghdad between the 1st and 6th February 1998.

Following the acceptance of UNSCR 687, Iraq was forced to destroy its remaining inventory of Scud missiles, warheads, and related equipment. Iraq had imported 819 warheads from the Soviet Union and had succeeded in producing warheads indigenously. During the period of warhead destruction, the distinction between the imported warheads and the indigenously produced warheads became unclear, and thus a full and accurate accounting for the destruction of imported and indigenously produced Scud warheads has never been reconciled.

- According to the NMD accounting (Tables 1 & 2), Iraq fired 87 imported warheads and six indigenously produced warheads (presumably concrete warheads for the Al Hijarah missiles) during the 1991 Gulf War. In the 1996 FFCD and the CAFCD, Iraq declared that it had fired 88 imported warheads and 5 indigenously produced Al Hijarah warheads. This leaves a discrepancy of one imported warhead.

- In the 1996 FFCD and the CAFCD, the Iraqis declared that they unilaterally destroyed 119 imported warheads. This NMD document shows only 118 had been destroyed.

- The disagreement between the numbers provided in the 1996 FFCD and the CAFCD, and this NMD document for the "special" CBW warheads destroyed by the Chemical Destruction Group, (CDG), is the largest. During this destruction of warheads, an accurate accounting for the number of imported versus indigenously produced warheads was never achieved.

Table 1

Accounting for Imported Soviet Scud Warheads (819 total)

		1996 FFCD & 2002 CAFCD
Returned to USSR	2	2
Fired during Iran-Iraq War	516	516
Test fired	57	57
Fired during 1991 Gulf War	**87**	**88**
Unilaterally destroyed	**118**	**119**
Destroyed under UN supervision	17	17
Special Warheads destroyed by CDG	**22**	**19**
Used in analysis	---	1
Total	819	819

This is a comparison of the figures derived from the NMD document and the 2002 CAFCD.

Table 2

Warheads Used by Purpose and Year

Year	Document #	Document Date	Warheads Exhausted	Remarks
1. Warheads used against Iran				
1980	2	20 Nov 1980	53	No indication to the number of warheads or code numbers
1981	5	21 Nov 1980	16	No indication to the number of warheads or code numbers
	7	03 Mar 1981	1	No warhead number or code. Launch failed and will be used for reverse-engineering
	8	07 Apr 1981	5	
	10	24 June 1981	3	
	13	27 Nov 1981	2	
	15	18 Dec 1981	2	
1982	3	04 May 1982	2	
	4	07 Jul 1982	8	
	7	21 Sept 1982	11	
	8	11 Sept 1982	3	
	10	19 Dec 1982	2	
1983	3	02 Feb 1983	4	
	9	19 May 1983	7	
	12	17 Aug 1983	2	
	13	08 Oct 1983	4	
	15	01 Nov 1983	10	
	16	18 Nov 1983	4	
	18	22 Dec 1983	5	
	19	30 Dec 1983	1	
1984	8	22 Feb 1984	15	
	9	05 Mar 1984	11	
	14	15 June 1984	9	
	21	06 Oct 1984	18	
1985	10	21 Mar 1985	54	
	11	03 Apr 1985	9	
	12	15 Apr 1985	13	
	16	03 May 1985	2	
	18	09 June 1985	4	
	22	14 June 1985	11	
1987	2	19 Jan 1987	27	
	7	27 Mar 1987	9	
1988	18	19 May 1988	189	
Total			516	
Year	Document #	Document Date	Warheads Exhausted	Remarks
2. Warheads Launched During the 1991 Gulf War				
1991	1	08 June 1991	87	No documents mention the [serial] numbers of the warheads. 93 total were launched, of which 6 were Iraqi made
	2	08 June 1991		
Total			87	

3. Warheads Launched in Training, Flight Tests, and Mineral Analyzation				
1977	6	Oct 1977	6	No warheads [serial] numbers mentioned in documents
1985	29	09 Aug 1985	1	No warheads [serial] numbers mentioned in documents
1987	16	04 May 1987	2	No warheads [serial] numbers mentioned in documents
	19	07 Aug 1987	1	No warheads [serial] numbers mentioned in documents
	25	05 Oct 1987	3	
	26	09 Oct 1987	1	
	27	18 Oct 1987	1	
	28	23 Nov 1987	2	
1988	1	02 Jan 1988	2	
	2	06 Jan 1988	1	Used for metal analysis
	16	15 June 1988	7	
	17	07 July 1988	3	
	19	03 Sept 1988	2	
	25	20 Nov 1988	3	
	26	02 Dec 1988	3	
1989	1	24 Feb 1989	2	
	3	07 July 1989	1	
	4	24 Aug 1989	1	
1990	1	07 Jan 1990	4	
	3	18 Apr 1990	1	No definition if warhead is Iraqi or Russian—suspect latter
	5	18 Apr 1990	1	
	11	09 May 1990	1	
Year	Document		Warheads	Remarks
	#	Date	Exhausted	
	12	09 July 1990	1	
	10	28 June 1990	1	No code or indication about the warhead
	21	02 Dec 1990	3	
	*	26 Dec 1990	1	* 2nd Division Orders doesn't reflect warhead code
	*	26 Dec 1990	2	* 2nd Division Orders doesn't reflect warhead code
Total			57	
4. Warheads Destroyed by UNSCOM				
1991	5	31 July 1991	17	
5. Special Warheads Destroyed by UNSCOM /CDG at Al Muthanna (Sept 1992 and April 1993)				
1992/3	**	Sept 92/Apr 93	22	**Verification certificate for the warhead destruction by UNSCOM in Sept 1992 and April 1993. Warheads were not indicated at the time but were later by both UNSCOM and Iraq. Now with UNSCOM (Bahrain)
6. Conventional Warheads Destroyed by Iraq in 1991 (Unilateral)				
1991	10	21 July 1991	118	
	13	22 Oct 1991		
7. Conventional Warheads Returned to Russia				
1980	3	03 April 1980	2	
Overall Total			819	

Official NMD document with the expenditure of 819 imported Scud warheads.

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Annex B
Liquid-Propellant
Missile Developments

2.1 Al Samud Program

In 1993, Iraq began developing liquid-propellant ballistic missiles. The program began as the Ababil-100 liquid-propellant missile program, which later became known as the Al Samud. This missile was based on SA-2 and Scud technology and manufacturing techniques; it was monitored closely by the UN. Research and development continued until 2001 when the program was terminated and replaced by the Al Samud II.

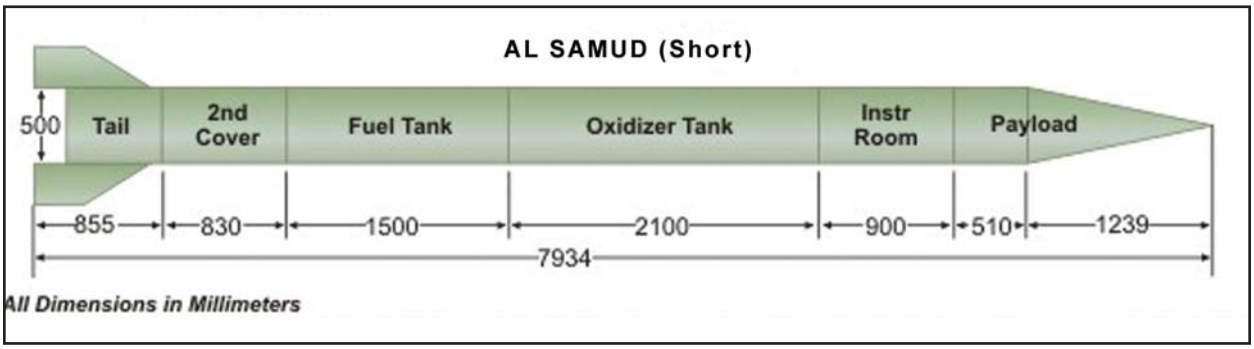

Figure 3. *Al Samud short diagram.*

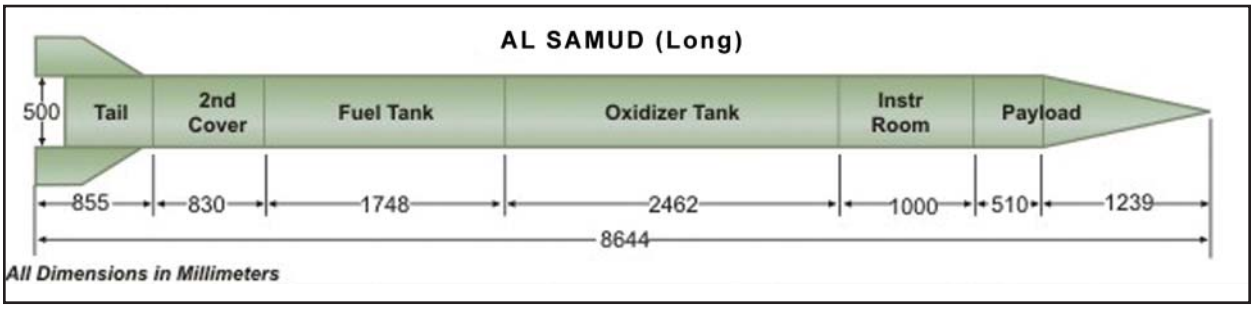

Figure 4. *Al Samud long diagram.*

Table 3

Original Al Samud Parameters

Subsystem	Parameter	Characteristic	Units	Data	Notes
Missile	Overall	Length	m	7.6	
		Diameter	mm	500	
		Lift-off mass	kg	1,500	Approximate figure
		Inert mass	kg	340	+/- 30kg
Warhead	Mass	Total	kg	270	
		Explosive	kg	160	60% TNT, 30% RDX, 10% Al
	Length	Overall	m	1.68	
		Cylindrical	m	0.23	
		Conical	m	1.45	
	Material	Wall	mm	3	Carbon steel
Propulsion	Engine	Thrust	t	3.5	
		Burning time	s	68*	Nominal
			s	+2*	Contingency
	Tanks	Ullage volume	%	5	Up to 8%
		Ox, length, overall	m	2.600	Domes each 0.335 high
		Ox, length, parallel	m	1.930	
		Fuel, length, overall	m	1.691	Domes each 0.335 high
		Fuel, length, parallel	m	1.021	
		Thickness	mm	2	Aluminum
	Propellant	Oxidizer	-----	AK-20K	
		Oxidizer flow rate	kg/s	11.5*	
		Total mass	kg	724*	Usable, for 63s burning time
		Fuel	-----	TG-02	
		Fuel flow rate	kg/s	3.5*	
		Total mass	kg	220*	Usable, for 63s burning time
Air supply	Air bottle	Diameter	mm	300	Spherical, one only
		Pressure	bar	300-360	

*Parameters are known to be inconsistent.

2.2 Al Samud Static Test Data

Table 4

Static Tests Supporting the Al Samud Program

#	Date		Fuel			Oxidizer			Filling Site	Notes
	Filled	Fired	Type	Source	Vol. (l)	Type	Source	Vol. (l)		(residual fuel, oxidizer)
01	00.10.96	00.10.96	TG-02	Bat. 76	210	AK-20K	Bat. 76	360	Bat. 76	IZ chamber & injector head
02	14.04.97	00.04.97	TG-02	Bat. 76	210	AK-20K	Bat. 76	360	Bat. 76	Structural test of missile
03	00.08.97	00.08.97	TG-02	Bat. 76	210	AK-20K	Bat. 76	360	Bat. 76	Structural test of missile
04	10.04.98	15.04.98	TG-02	Bat. 76	210	AK-20K	Bat. 76	360	Bat. 76	
05	20.04.98	22.04.98	TG-02	Bat. 76	210	AK-20K	Bat. 76	360	Bat. 76	
06	00.06.99	07.06.99	TG-02	Bat. 76	210	AK-20K	Bat. 76	360	Bat. 76	Check IZZ engine
07	00.07.99	00.07.99	TG-02	Bat. 76	210	AK-20K	Bat. 76	360	Bat. 76	Check IZZ engine
08	21.07.99	22.07.99	TG-02	Bat. 76	210	AK-20K	Bat. 76	360		
09	06.08.99	07.08.99	TG-02	Bat. 76	210	AK-20K	Bat. 76	360	Bat. 76	Check IZZ purge system
10	22.11.99	23.11.99	TG-02	Bat. 76	210	AK-20K	Bat. 76	360	Bat. 76	Check telemetry
11	04.12.99	05.12.99	TG-02	Bat. 76	210	AK-20K	Bat. 76	360	Bat. 76	Check telemetry
12	13.07.00	15.07.00	TG-02	Karamah	210	AK-20K	Karamah	360	Bat. 76	
13	05.08.00	08.08.00	TG-02	Karamah	242.5	AK-20K	Karamah	402.5	Bat. 76	(10, 41)
14	06.09.00	07.09.00	AZ-11	China	267	AK-20K	USSR	463	Bat. 76	Tb 61s, (2, 2.5)
15	11.10.00	12.10.00	AZ-11	?	267	AK-20K	USSR	430	Bat. 76	IZ regulator, tb 69s (2.5, 2)
16	16.10.00	17.10.00	TG-02	USSR	267	AK-20K	USSR	431.5	Bat. 76	Tb 61s
17	17.03.01	18.03.01	AZ-11		266	AK-20K	USSR	428	Bat. 76	Repeat of 16
18	03.04.01	03.04.01	TG-02	USSR	275	AK-20K	USSR	442	Bat. 76	IZZ turbo-pump
19	25.04.01	26.04.01	TG-02	USSR	285	AK-20K	USSR	460	Bat. 76	IZZ vanes [TVC]
20	11.06.01	12.06.01	TG-02	USSR	271	AK-20K	USSR	451	Bat. 76	Tb 58s, original engine
21	16.10.01	17.10.01	TG-02	USSR	216	AK-20K	USSR	357	Bat. 76	IZZ turbo-pump, tb 49s, (22, 8)
22	28.11.01	29.11.01	AZ-11	?	191	AK-20K	USSR	352	Bat. 76	Tb 45s, (10, 40)
23	16.02.02	17.01.02	AZ-11	?	190	AK-20K	Al Qa'qa'a	350	IAH	Tb 49s, (8, 19)
24	01.04.02	02.04.02	TG-02	USSR	210	AK-35K	Ibn-Sina'	350	Bat. 76	Test effects of AK-35K

Multiple source entrees
Single source entrees

Al Samud Flight Tests

	Date Launched	ZTime	Range (km)	Date Filled	TG-02 (liters)	AK-20K (liters)
1	24-Oct-1997	unk	92		210	360
2	20-Feb-1998	1323	93		210	360
3	21-Feb-1998	1000	0		210	360
4	22-Feb-1998	unk	0		210	360
5	30-Mar-1998	unk	15			
6	1-May-1998		15km		210	360
7	1-Jun-1998		Failed		210	360
8	4-Aug-1998	600	0			
9	11-Aug-1998	940	71.8			
10	20-Oct-1998	715	0			
11	20-Oct-1998	1250	0			
12	1-May-1999	unk	n/a	30-Apr-99	210	360
13	10-May-1999	unk	20			
14	30-Aug-1999		n/a		210	360
15	5-Sep-1999	415	n/a			
16	23-Dec-1999		Failed		210	360
17	28-Dec-1999	1315	55	28-Dec-99	210	360
18	17-Feb-2000	938	72	15-Feb-99	210	360
19	12-Mar-2000	1315	90	11-Mar-99	210	360
20	25-Apr-2000	1201	70	24-Apr-00	212	365
21	23-May-2000	1030	100	22-May-00	212	365
22	1-Sep-2000	606	0			
23	26-Oct-2000	unk	n/a			
24	13-Nov-2000		n/a	11-Nov-00	281	453
25	20-Nov-2000	1215	151	20-Nov-00	279	452
26	12-Dec-2000	830	50	10-Dec-00	286	461

Figure 5. *Al Samud flight tests (1997-2000).*

Multiple source entrees
Single source entrees

Al Samud Flight Tests

	Date Launched	ZTime	Range (km)	Date Filled	TG-02	AK-20K
27	13-Jan-2001	802	120	11-Jan-01	286	463
28	14-Jan-2001	1039	n/a			
29	21-Jan-2001	1125	Failed	20-Jan-01	278	452
30	12-Feb-2001	907	56	8-Feb-01	278	452
31	16-Feb-2001	846	150	16-Feb-01	279	450
32	20-Mar-2001	842	150	20-Mar-01	279	452
33	28-Mar-2001		30km	27-Mar-01	279	452
34	28-May-2001	unk	Failed	25-May-01	280	460
35	28-May-2001		87km	25-May-01	280	460
36	28-May-2001		90km	26-May-01	280	460
37	29-May-2001		85km	29-May-01	240	355
38	11-Jul-2001	314	88	11-Jul-01	230	376
39	12-Jul-2001	340	Failed	12-Jul-01	230	376
40	17-Jul-2001		n/a	15-Jul-01	230	376
41	20-Aug-2001	359	n/a	19-Aug-01	230	376
42	20-Aug-2001		85km	19-Aug-01	230	375
43	20-Aug-2001		45km	19-Aug-01	217	357
44	24-Sep-2001		n/a	23-Sep-01	217	355
45	24-Sep-2001		n/a			
46	26-Sep-2001		74km	26-Sep-01	217	358

Figure 6. *Al Samud flight tests (2001).*

2.4 Al Samud II Static Test Data

Table 5

Static Tests Supporting the Al Samud II

#	Date		Fuel			Oxidizer			Filling Site	Notes
	Filled	Fired	Type	Source	Vol. (l)	Type	Source	Vol. (l)		(residual fuel, oxidizer) (in liters)
01	31.07.01	01.08.01	TG-02	AK-20K	347	AK-20K	USSR	557	Bat. 76	Tb 74s, (15, 12)
02	07.03.02	08.03.02	AZ-11		370	AK-20K	Qa'qa'a	597	IAH	Tb 85s, (14, 18)
03	26.03.02	27.03.02	TG-02	Raya	364	AK-20K	Qa'qa'a	601	IAH	Tb 75s, (33, 10)
04	07.04.02	08.04.02	TG-02	Raya	386	AK-20K	Raya	605	IAH	Stabilizer test (70, 35)
05	15.05.02	16.05.02	TG-02	Raya	371	AK-20K	Qa'qa'a	603	IAH	T-pump test, tb 30, leak!
06	01.07.02	01.07.02	TG-02	Raya	375.5	AK-22K	Qa'qa'a	612	IAH	IZZ chamber, (66, 15)
07	08.07.02	08.07.02	TG-02	Raya	375	AK-20K	Qa'qa'a	?	IAH	Failed, oxidizer pipe leak
08	16.07.02	16.07.02	TG-02	Raya	370.9	AK-20K	Qa'qa'a	609	IAH	IZZ vanes, orig engine - Fail
09	31.07.02	01.08.02	TG-02	Raya	371	AK-20K	Qa'qa'a	609	IAH	Tb 81s, IZZ vanes (36, 2)
10	07.08.02	07.08.02	TG-02	Raya	370	AK-20K	Qa'qa'a	607	IAH	IZZ gas generator
11	29.08.02	30.08.02	TG-02	Raya	370	AK-20K	Qa'qa'a	614	IAH	IZZ chamber, ok
12	05.09.02	06.09.02	TG-02	Raya	375	AK-20K	Qa'qa'a	614	IAH	Engine burnt - Fail
13	09.11.02	n/a	TG-02	Raya	372	AK-20K	Qa'qa'a	598	IAH	IZZ t-pump, (13, 20) OK
14	16.11.02	16.11.02	TG-02	Raya	372	AK-20K	Qa'qa'a	598	IAH	IZZ t-pump (37, 36)
15	24.11.02	25.11.02	TG-02	Raya	370	AK-20K	Qa'qa'a	605	IAH	IZZ engine, tb20s,(436 ox) F
16	04.12.02	05.12.02	TG-02	Raya	368	AK-20K	Qa'qa'a	601	IAH	Tb 78s, (3, 12) OK
17	02.01.03	02.01.03	TG-02	Raya	368	AK-20K	Qa'qa'a	601	IAH	Orig engine, IZZ vanes (25, 27)
18	11.01.03	12.01.03	TG-02	Karamah	369	AK-20K	Raya	606	Taji	IZZ engine, (15, 55) OK
19	26.01.03	27.01.03	TG-02	Karamah	365	AK-20K	Qa'qa'a	602	IAH	IZZ engine, (0, 48.5) OK
20	03.02.03	04.02.03	TG-02	Karamah	368	AK-20K	Qa'qa'a	605	A Ghraib	Tb 81s, IZZ vanes (28, 26.5)
21	22.02.03	23.02.03	TG-02	Karamah	366	AK-20K	Qa'qa'a	605	A Ghraib	New TVC vane material

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2.5 Al Samud II Flight Test Data

Multiple source entrees
Single source entrees

Al Samud II Flight Tests										
	Date Launched	**ZTime**	**Range (km)**	**Date Filled**	**TG-02 (literes)**	**AK-20K (liters)**	**Propellant Temp**	**Temp of Air**	**Wind Speed (m/s)**	**Wind Direction**
1	24-Aug-2001		n/a	23-Aug-01	344	555				
2	26-Sep-2001	1332	154	25-Sep-01	357	613.5	28°C	22°C	10	246°
3	11-Oct-2001	unk	142	9-Oct-01	612	381	28°C	20°C	14	169°
4	6-Nov-2001	unk	Failed	4-Nov-01	376	611.5				
5	7-Nov-2001	630	154.2	6-Nov-01	375	604.5	22°C	28°C	21	306°
6	29-Dec-2001	unk	33	27-Dec-01	369 ®	600 (Q)				
7	9-Jan-2002	949	155.9	7-Jan-02	370 ®	600 (Q)	15°C	20°C	6	206°
8	10-Jan-2002	unk	140	8-Jan-02	367 ®	596 (Q)	11°C	15°C	7	212°
9	31-Jan-2002	1229	171	30-Jan-02	367 ®	600.5(Q)	12°C	15°C	12	122°
10	14-Mar-2002	unk	180.5	12-Mar-02	370 ®	598 ®	24°C	20°C	12	202°
11	11-Apr-2002	unk	164	11-Mar-02	370 ®	604 ®	n/a	n/a	n/a	n/a
12	10-May-2002	unk	183	8-May-02	398*	632	n/a	n/a	n/a	n/a
13	6-Jun-2002	unk	145	5-Jun-02	386 ®	636 ®	30°C	25°C	15	208°
14	17-Jun-2002	307	156.6	16-Jun-02	387 ®	632 ®	31°C	9°C	10	192°
15	18-Jun-2002	312	136.7				31°C	10°C	12	226°
16	18-Jul-2002	354	153	17-Jul-02	376 ®	612 (Q)	37°C	31°C	12	311°
17	18-Jul-2002	unk	n/a							
18	23-Jul-2002	256	152.2	n/a	376 ®	620 (Q)	n/a	n/a	n/a	n/a
19	25-Aug-2002	345	174	n/a	375(K)	607 (Q)				
20	25-Aug-2002	unk	163	n/a	375(K)	614 (Q)				
21	30-Oct-2002	604	124	24-Aug-02	375(K)	612 (Q)				
22	30-Oct-2002	812	25	24-Aug-02	375(K)	612 (Q)				
23	16-Nov-2002	unk	166	14-Nov-02	374(K)	612 (Q)				

Figure 7. *Al Samud II flight tests.*

Al Samud II Flight Tests (continued)		
	Lateral Deviation	**Source Comments and Deviations**
1		“Result n/a. & Filled at Battery 76”
2	1°-Left	“Filled at Battery 76, Flight date 25-Sep-2001 & Range 145km”
3	0.5°-Left	“Filled at Battery 76”
4		“Failed on the pad. & Filled at Bat. 76”
5	1.76°-Left	“Filled at Battery 76 & Range 154km”
6		“Filled at Ibn al Haytham & Range 35km”
7	2°-Right	“Missile # 020214 & Range 154km”
8	10°-Right	“Missile # 010203”
9	0.68°-Left	“Range 170km”
10	3.07°-Left	“Range 181km” & “9th Al Samud 2 luanch”
11	n/a	“Range 165km”
12	1°-Left	“*Used AZ-11 & Filled at Ibn al Haytham” & “Range 184km”
13	3.67°-Left	
14	1.63°-Right	“Result n/a”
15	2.06°-Right	
16	0.75°-Left	“Missile #63”
17		
18	0.14°-Left	“83s burning time, Missile #66 & Range 152km”
19		“174km (vs 125 theoretical), Missile #67 & 80s burn time”
20		“163km (vs 100 theoretical), Missile#68, & 82.4s burn time”
21		“Missile #69” & “Range 75km”
22		“Missile #70” & “Range 24km”
23		“Result n/a”

Figure 7. *Al Samud II flight tests (continued).*

2.6 Al Samud II Missile Material Balance

Materials Balance

To determine the likely number of missiles that could potentially remain in an inventory, the technique of materials balance can be employed. This involves the collection of data associated with all aspects of the production and consumption of the missiles concerned. The production numbers may be gleaned from the factory producing the hardware or where the missiles are integrated or even loaded with propellants. Consumption numbers can be derived from tests, either static or flight, deliveries to the armed forces or those withdrawn due to damage or other causes.

If a materials balance of complete missiles cannot be accomplished, an equivalent might be derived from the many subsystems that make up the complete missile—such as warheads, engines, or even propellants. This latter approach has been used in an attempt to account for both Scud and Al Samud II missile inventories.

ISG believes that a complete material balance for the Al Samud II missile may not be possible due to various factors. Documentary data indicating the total number of missiles produced have not been recovered by ISG and the disposition of the missiles is unknown. However, a very good estimate of the total number produced can be achieved based on the knowledge that the Iraqis had a production rate goal of 10 per month, according to an official in Iraq's missile program. This rate varied month to month due to availability of parts. The missile began production in late 2001 with the first 10 being delivered to the Army in December 2001. ***Assuming these production figures were maintained between December 2001 and December 2002, ISG believes a likely total of 130 Al Samud II missiles may have been produced during this period.*** According to a former senior official at Al Karamah, Iraq produced approximately 20 missiles during the first quarter of 2003. Another source claimed that, after UNMOVIC inspectors departed the country in March 2003, Iraq was able to assemble about 4 Al Samud missiles from remaining parts, which had been placed in mobile trucks to avoid destruction. ***These 24, in addition to the 130 previously mentioned, yield a total of 150 Al Samud II missiles produced.***

According to multiple sources, Iraq expended up to 27 missiles during experimental tests (flight and static tests). Beginning 1 March 2003, UNMOVIC began a destruction program, which accounted for 72 missiles destroyed. ISG have obtained information given in Table 6, which shows serial numbers associated with 62 of the 72 missiles destroyed. However, the dates of destruction do not appear to correlate to those dates provided by the UNMOVIC spokesman during the period of destruction. According to reporting, Iraq launched five Al Samud II missiles during OIF. Table 7 details some of the additional al Samud subsystems destroyed under UNMOVIC supervision. Coalition forces may have been responsible for the destruction and recovery of up to 15 missiles based on available data. According to a foreign government service, two Al Samud II missiles were taken to Iran. ISG has not been able to confirm this claim. ***Taking these figures into account, ISG has developed possible scenarios for material balance for the Al Samud II missile given in Table 6***

Table 6

Al Samud II Missiles Destroyed Under UNMOVIC Supervision in 2003

Date	Serial No.	Date	Serial No.	Date	Serial No.
03 Mar 03	020279	06 Mar 03	020294 TE	11 Mar 03	020233
03 Mar 03	020272	06 Mar 03	020297 TE	11 Mar 03	020283
03 Mar 03	020228	06 Mar 03	020302 TE	11 Mar 03	020232
03 Mar 03	020226	07 Mar 03	010206 TL	12 Mar 03	020237
03 Mar 03	020236	07 Mar 03	020310 TL	12 Mar 03	020236
03 Mar 03	020229	07 Mar 03	020308 TL	12 Mar 03	020292
04 Mar 03	020296	08 Mar 03	020280	13 Mar 03	020314
04 Mar 03	020295	08 Mar 03	020288	13 Mar 03	020313
04 Mar 03	020286	08 Mar 03	020287	13 Mar 03	020316
05 Mar 03	020217 TE	08 Mar 03	020306	14 Mar 03	020311
05 Mar 03	010227 TE	08 Mar 03	020209	14 Mar 03	020312
05 Mar 03	020264 TE	08 Mar 03	020303	14 Mar 03	020299
05 Mar 03	020284 TE	09 Mar 03	020285	14 Mar 03	020315
05 Mar 03	020277	09 Mar 03	020282	15 Mar 03	020235
05 Mar 03	020278	09 Mar 03	020281	15 Mar 03	020234
05 Mar 03	020273	09 Mar 03	020304 TE	15 Mar 03	020290
05 Mar 03	020274	09 Mar 03	020291 TL	16 Mar 03	020220
05 Mar 03	020293	09 Mar 03	020289 TL	16 Mar 03	020242
06 Mar 03	020222	10 Mar 03	020225	17 Mar 03	020240
06 Mar 03	020227	10 Mar 03	020224	17 Mar 03	020221
06 Mar 03	020275	10 Mar 03	020298		

No.	Engine Serial No.	Fuel Tank Serial No.	Oxidizer Serial No.	Tail Serial No.	Warhead Serial No.
1	57013	FU-125	Ox-115	109	130
2	56820	FU-132	Ox-120	118	133
3	89834	FU-113	Ox-127	121	134
4	88240	FU-123	Ox-102	120	135
5	50413	FU-115	Ox-126	102	136
6	57007	FU-129	Ox-132	111	122
7	82439	FU-117	Ox-121	112	124
8	57918	FU-111	Ox-124	113	120
9	82551	FU-134	Ox-123	119	121
10	27736	FU-114	Ox-125	126	115
11	31414	FU-121	Ox-118	117	132
12	53005	FU-130	Ox-140	124	131
13	53401	FU-138	Ox-135	126	128
14	82626	FU-142	Ox-138	128	118
15	54115	FU-139	Ox-136	131	116
16	82414	FU-140	Ox-129	123	119
17	89720	FU-145	Ox-122	132	126
18	55404	FU-116	Ox-131	130	113
19	51725	FU-133	Ox-117	127	117
20	54108	FU-135	Ox-128	125	103
21	80120	FU-127	Ox-130		114
22	89925	FU-126	Ox-133		
23	113741	FU-128	Ox-134		
24	52916	FU-103	Ox-141		
25	55017		Ox-092		
26	54418		Ox-104		

Table 7

Additional Al Samud II Subsystems Destroyed Under UNMOVIC Supervision

	Worst Case	Likely Case	Best Case
Missiles Produced	150	130	121
Used in tests	22	25	27
Destroyed under UNMOVIC	72	72	72
Launched during OIF	5	5	5
Damaged/Captured/to Iran	15	15	17
Unaccounted for	36	13	0

Table 8

ISG Assessment of Al Samud II Missile Accountability

The Liquid Fuels Committee (LFC)

Until April 1998, both the Air Defense and the Naval Defense and the Naval Defense forces had supplied Al Karamah with whatever propellant was required for testing on an ad hoc basis. Both felt unable to continue this relationship as it was adversely affecting their own propellant stocks. On hearing this news, Staff Lt. Gen. Muzahim Sa'b Hasan Muhammad Al Nasiri called a meeting of representatives from the Military Industrialization Commission (MIC), the Army (Surface-to-Surface Missile [SSM] Command), Air Defense Forces, Al Karamah, and the Naval Defense Forces. The armed forces could satisfy their own propellant requirements but, for Al Karamah's new development program, there was none available. Thus, arrangements had to be made to satisfy this need whilst maintaining stock availability to the other armed services. To do this, a committee called the LFC was set up by the MIC in 1998 to manage and coordinate the requirements of all liquid-propellant research, production, and supply (regeneration, manufacture, or importation) to the various users.

There were three goals of the LFC:

1. *Now - To ensure the continued supply for current requirements of TG-02 and AK-20K*
2. *Near Term - The production of AZ-11 and AK-27P*
3. *Far Term - The production of Hydrazine, Unsymmetrical Di-Methyl Hydrazine (UDMH), Nitrogen Tetroxide, and Hydrogen Peroxide*

By the time of Operation Iraqi Freedom (OIF), objective 1 was achieved, some movement was in progress toward objective 2, and most of the candidate propellants in objective 3 were at least being researched.

The LFC consisted of the following personnel:

Name	***From, Position***	***Notes***
Dr. Muzhir [Modher] Sadiq Saba' Khamis Al-Tamimi	*Al Karamah, DG*	*Chairman*
Jasim Muhammad Salman al-Tamimi	*Al Karamah*	*Deputy Chairman*
Dr. Yusif 'Ulwan Hammadi Al 'Ithawi	*Ibn-Sina', DG*	
Dr. Hikmat Na'im Al Jalu	Ibn-Sina', former DG	
Dr. Thabit Jasim	Ibn-Sina', former DG	
Ghazi Faysal Najm-al-Din	Al Basil	
Dr. Zuhayr Mahmud Al Qazzaz	Al Basil	
Dr. Jalil Rahif' Akal	Al Basil	
Dr. Agil 'Awad	Al Basil	
Dr. Jasim	Al Kindi	
Fu'ad Muhammad Basim	Al Qa'qa'a	
Sami Da'ud	Sa'd Company	Al Zahrawi Center
Dr. Hamzah Yasin 'Issa	MIC Center	
Dr. Ghanim Maqbul 'Ulwan	Al Amin	

2.7 Liquid-Propellant Material Balance

Closure of the material balance for liquid propellants is extremely difficult because of the amount of regeneration due to the effects of aging on propellants. The records kept concerning regeneration do not make reference to the sources of fresh material acquired in the regeneration process. Instead, they provide only an input-output picture.

The Liquid Fuels Committee (LFC) was initiated in August of 2000 to analyze performance capabilities for various propellants, research techniques for producing candidate chemical propellants or their precursors, and study synthesis routes and manufacturing capabilities of various companies. Through studies of companies and capabilities, the LFC awarded contracts to companies to begin manufacturing. The projected production capabilities were 50 tons/yr of Di-methyl amine (DMA), 20 tons/yr of DETA, 50 tons/yr of TEA, and 50 tons/yr of xylidine. Schematics of liquid-propellant production and research are shown in Figures 8 and 9. *This production when combined with the imported quantities of propellant far surpassed the requirements of the Al Samud II program.* A schematic materiel balance of the liquid propellant used for the Al Samud II program is shown below in Figures 10 through Figure 12, with the production or sources along the top, above the total and consumption along the bottom of each table.

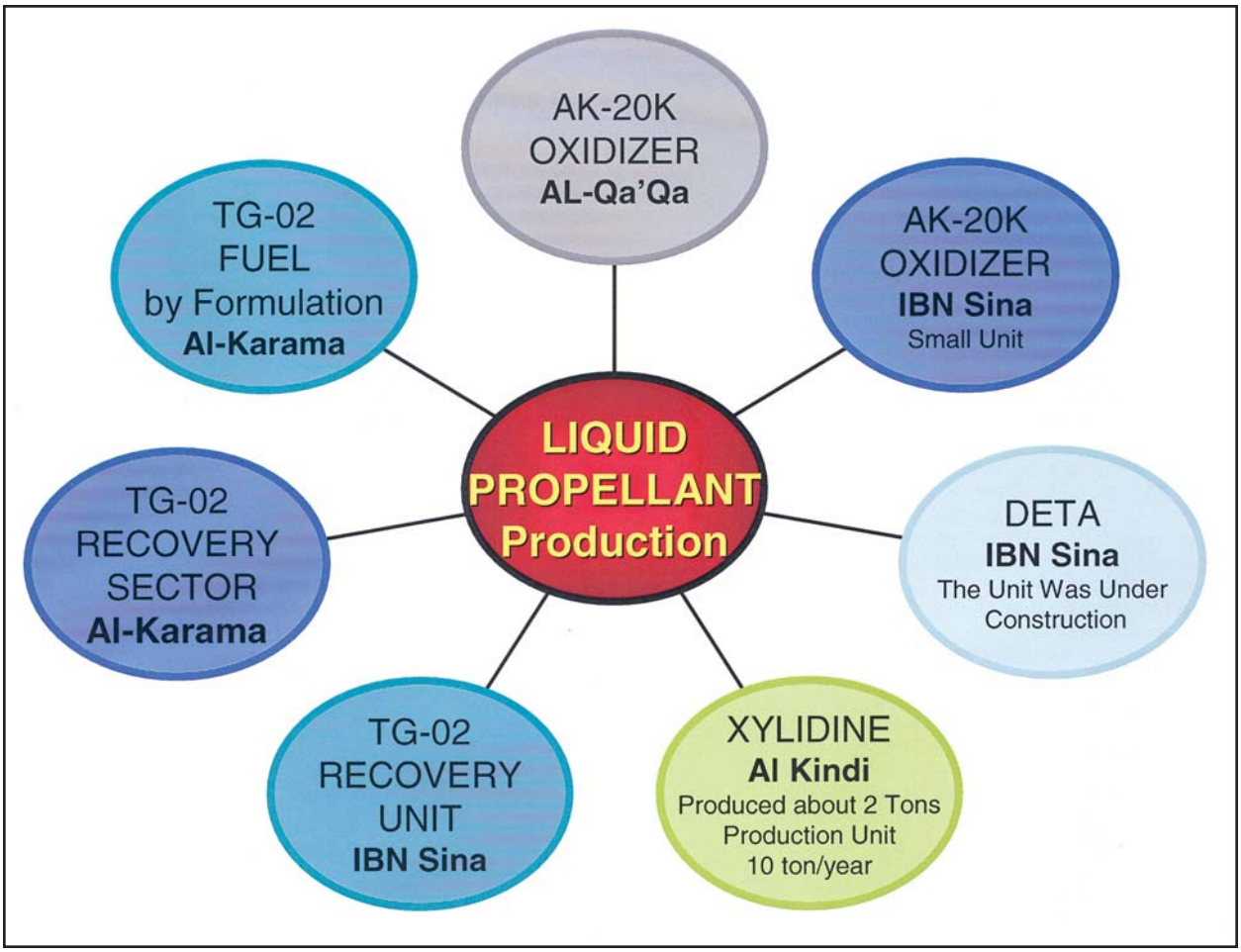

Figure 8. *Liquid-propellant production.*

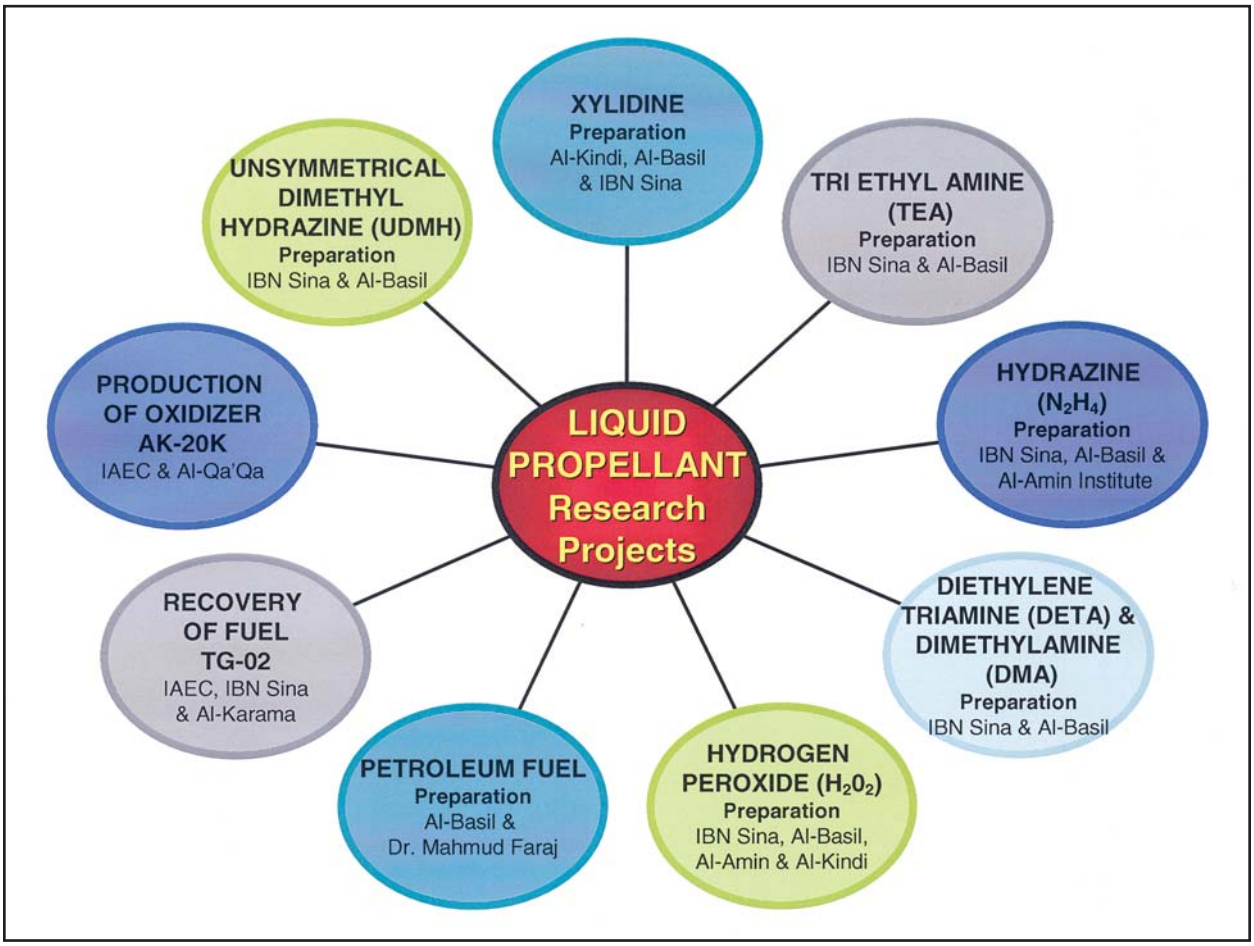

Figure 9. *Liquid-propellant research.*

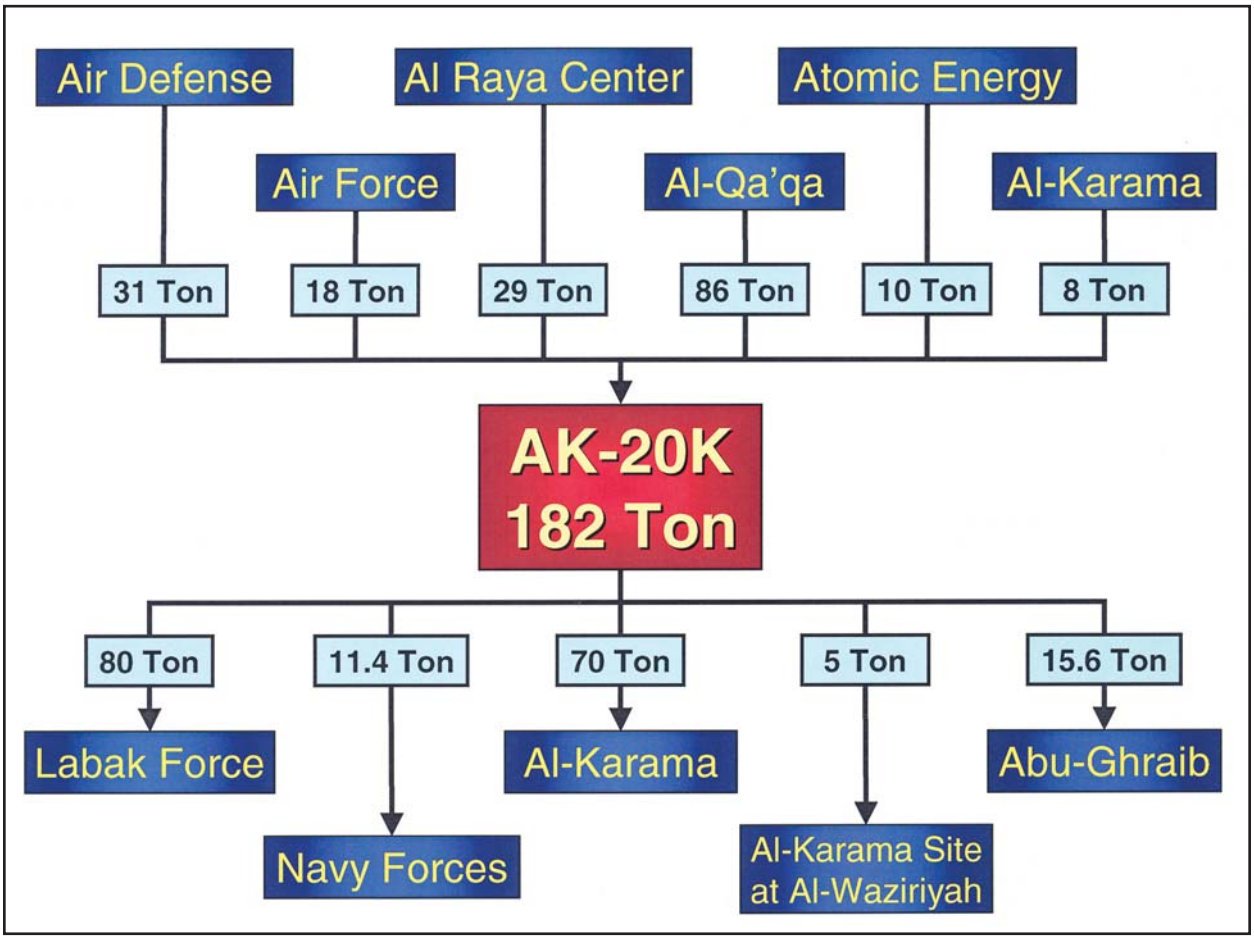

Figure 10. *Oxidizer materiel balance (1995-2003).*

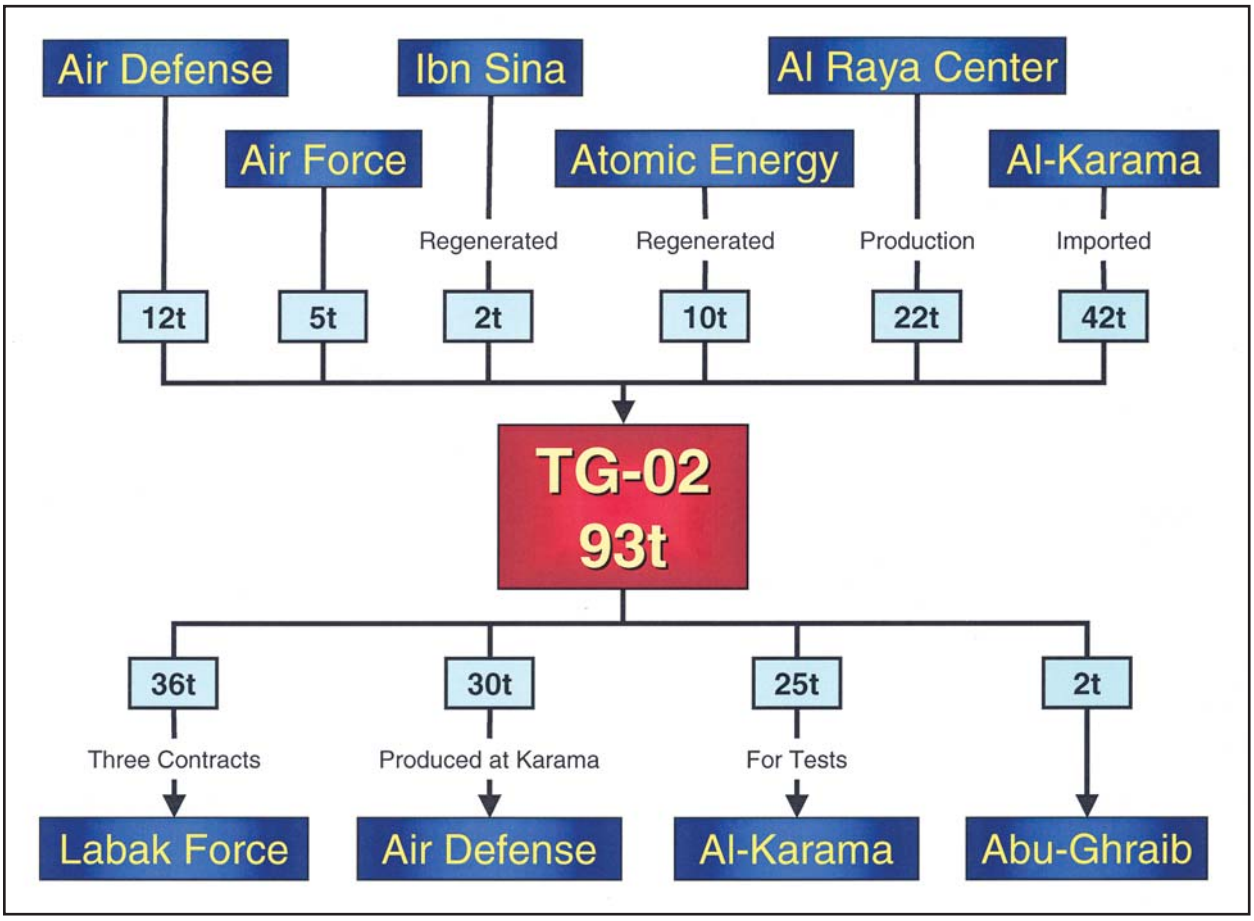

Figure 11. *Fuel materiel balance (1995-2003).*

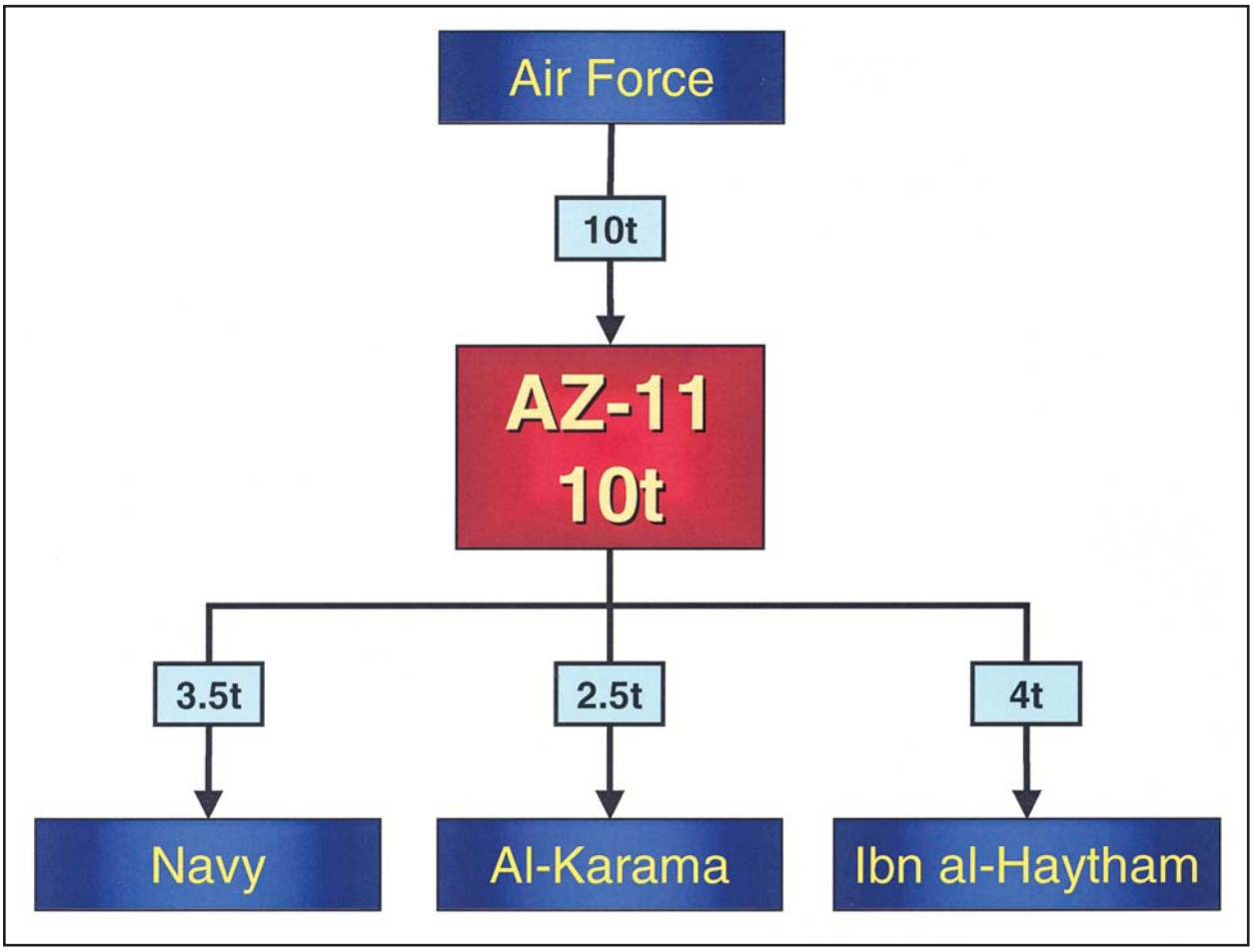

Figure 12. *High-energy propellant materiel balance (1995-2003).*

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Annex C
Solid-Propellant
Missile Developments

3.1 Iraqi Composite Solid-Propellant Composition

The composite propellants fielded by Iraq were "conventional," being formulations widely used throughout the industry and based on a hydroxyl-terminated poly butadiene (HTPB) binder heavily loaded with ammonium perchlorate (AP) and aluminum powder. In addition to these main chemicals, a number of other chemicals are used, such as plasticizer, burning rate modifiers and curing agents.

Table 9

The Al Fat'h and Al 'Ubur Propellant Formulation

Compound	% by mass
Ammonium Perchlorate (AP) (200-Micron Particle Size)	35
Ammonium Perchlorate (AP) (50-80 Micron Particle Size)	35
Aluminum Powder (< 200 Micron particle Size)	14
Hydroxy Terminated Poly Butadiene (HTPB)	11-12
Dioctyl Azelate (DOZ) - or - Dioctyl Adepate (DOA)	3.5
Ferric Oxide	1
2,4-Toluene Diisocyanate (TDI)	~1
Tri[1-(2-Methyl Aziridinyl)] Phosphine Oxide (MAPO)	0.3

Of these ingredients, none are explicitly prohibited. UNSCR 715 Annex IV references chemicals subject to monitoring and verification, although the Import/Export Mechanism approved by UNSCR 1051 requires prior notification of imports. The Missile Technology Control Regime (MTCR) refers to Category II chemicals, which are subject to case by case review. Many of these chemicals are classified as "Dual Use," meaning they may have other uses. The primary components of the Iraqi composite solid-propellant ingredients fall within these control classifications as shown in Table 10.

Table 10

The Al Fat'h and Al 'Ubur Propellant Control Classifications

Chemical	UNSCR 715/1051	MTCR Cat II	Dual Use
Ammonium Perchlorate (AP)	Y	Y	N
Aluminum Powder	N	Y	Y
Hydroxyl Terminated Poly Butadiene (HTPB)	Y	Y	Y
Dioctyl Azelate (DOZ)	N	N	Y
Ferric Oxide (FE2O3)	Y	Y	Y
2,4-Toluene Diisocyanate (TDI)	N	N	Y

3.2 Iraqi Composite Solid-Propellant Infrastructure

To support its solid-propellant program, Iraq constructed, rebuilt, or repaired equipment and facilities destroyed by UNSCOM or Coalition forces. The Iraqi effort was relatively successful at indigenous production, although some key materials still had to be imported. The Iraqi composite solid-propellant capabilities were centered initially in the Al Kindi General Company and the Al Rashid General Company. Due to the lack of involvement with ballistic missile developments, Al Kindi and its associated facilities will not be discussed in detail in this document.

The Al Rashid General Company (see Figure 13) controlled most if not all of the major solid-propellant missile initiatives and the related production facilities.

The Al Fat'h Company functioned primarily in a design, project management, and oversight role for the Al Fat'h missile. Headquartered in the Al 'Amiriyah section of Baghdad, the company was founded in 1996 at Ibn-al-Haytham and moved to Al 'Amiriyah in the late 1990's.

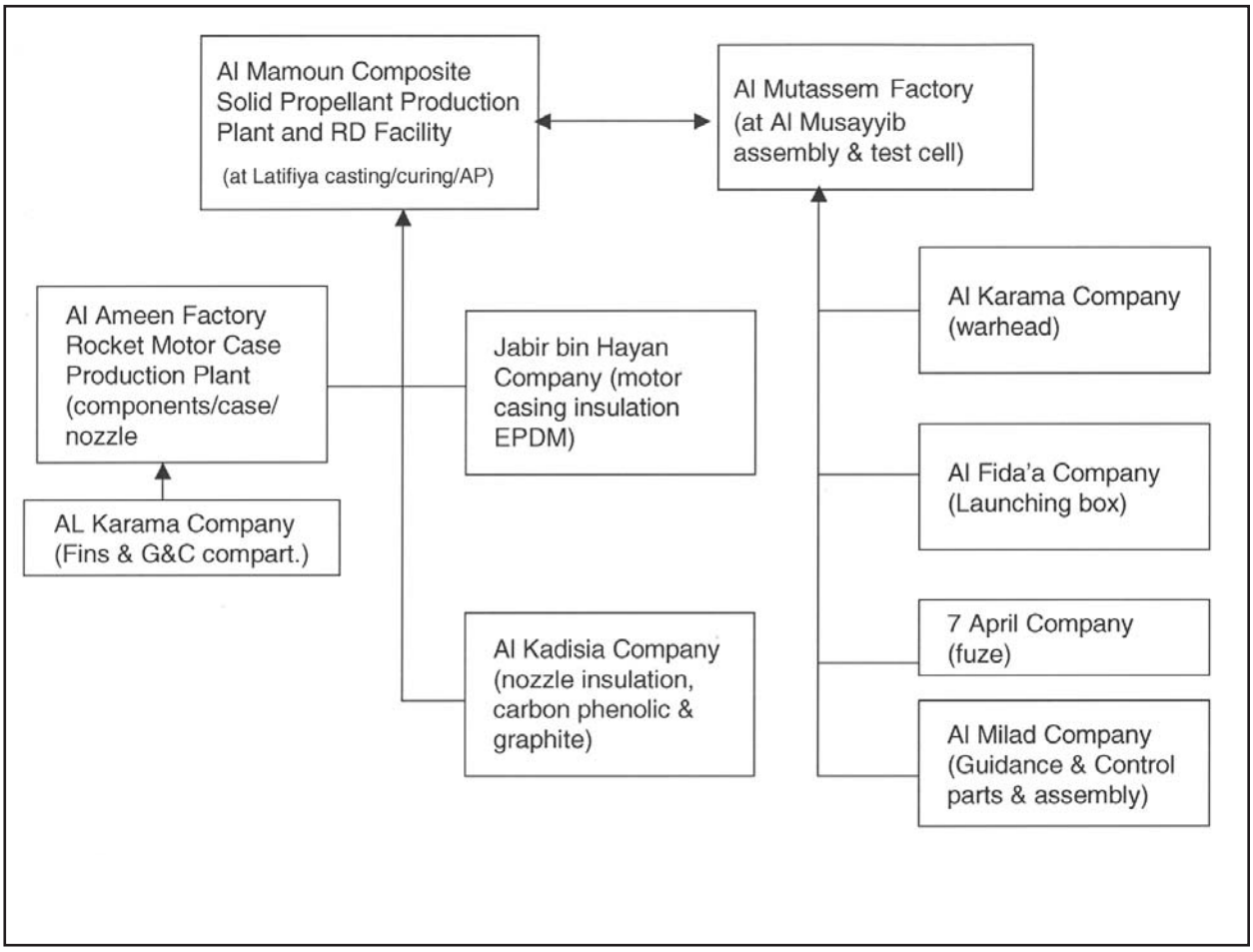

Figure 13. *Al Rashid organizational structure.*

Within the Al Rashid State Company, the Al Ma'mun Factory was the center of composite solid-propellant research and production. Within the complex were facilities for composite propellant mixing, casting and curing. In addition, R&D efforts in the area of composite propellants were conducted.

The Al Musayyib Solid Rocket Motor Factory at Al Mutasim contained horizontal rocket motor test cells and motor assembly buildings. All of the known Al Rashid associate solid-propellant static tests were conducted at Al Musayyib.

The Al Amin Factory and Thu-al-Fiqar [Tho-al-Fekar] Factory produced motor casings and nozzles.

3.3 Al Fat'h Missile Technical Specifications

The Al Fat'h was originally intended to be produced in two variants, guided and unguided. The missile was a solid-propellant ballistic missile weighing approximately 1,200 kg with an overall length of approximately 6.7 m and a diameter of 0.5 m for the main body and 1.4 m with the aft fin assembly. During the development of the system, large inaccuracies in the unguided variant were encountered. All the Al Fat'h missiles recovered to date are unguided. The Al Fat'h was designed to be launched from a Transporter-Erector-Launcher (TEL) based upon the Volga (SA-2) missile launcher. The composite propellants utilized in the Al Fat'h are "conventional," being a general

formulation widely used throughout the industry. The propellant is based on a Hydroxyl Terminated Poly Butadiene (HTPB) binder heavily loaded with Ammonium Perchlorate (AP) and aluminum powder. In addition to these main chemicals, a number of other chemicals are used, such as plasticizer, burning rate modifiers, and curing agents.

3.4 Al Fat'h Missile Manufacturing Difficulties

There were apparently three aspects of the Al Fat'h manufacturing process that presented the Iraqis with significant challenges. **The first was the unavailability of maraging steel sheets of sufficient size.** Maraging steel has the advantage of being easy to form in its original state, but when annealed, to provide excellent properties as far as rigidity, strength, and crack resistance. Without maraging steel, the Al Fat'h had to be constructed from 30CrMoV9 sheet steel. Forming this sheet steel into the cylingrical shapes needed for the rocket motor casing and airframe was difficult and created problems.

A second manufacturing issue in the construction of the Al Fat'h was the lack of large propellant mixing capabilities. The original 1,200-liter (300 gallon) propellant mixers acquired through the BADR-2000 program were destroyed by the UN. Although at least two of the bowls and one or both mixers were restored by Iraq, these were in turn destroyed by the Iraqis prior to the return of the UN in 2002 and hidden. Either way, the equipment was unavailable for use in the propellant mixing for the Al Fat'h rocket motor. The Al Fat'h contained approximately 830 kg of propellant. While the BADR-2000 bowls would have provided the capability of easily filling the Al Fat'h motor in a single pour, the lack of these bowls forced the Iraqis to use four or five smaller 120-liter (30 gallon) bowls. These bowls, mixed in two available mixers, were then poured sequentially into the motor casing. A senior Iraqi official stated the process worked well but admitted that one out of every 10 motors exploded during motor burn. In addition, this process also eliminated the possibility of multiple simultaneous motor castings.

The final major manufacturing issue was the inability to completely indigenously manufacture the G&C system for the Al Fat'h. The Al Fat'h was intended to use a strap-down inertial guidance system. A highly accurate strap-down system with digital flight computer, coupled with an adequate canard terminal guidance system, would most likely have provided the Al Fat'h with an accuracy that met the specified 150 m CEP accuracy for the guided variant at a range of 150 km. This level of accuracy, coupled especially with the submunition warhead, would have made the Al Fat'h a more accurate and lethal tactical weapon system.

3.5 Al Fat'h Missile Program Organization

As previously mentioned, while the Al Fat'h General Company was responsible for design and program management aspects of the Al Fat'h program, the Al Rashid General Company was primarily the manufacturer. The Al Rashid General Company utilized a variety of subordinate companies and contracted sources in the manufacturing process. The general organization of Al Rashid is presented in Figure 14 below.

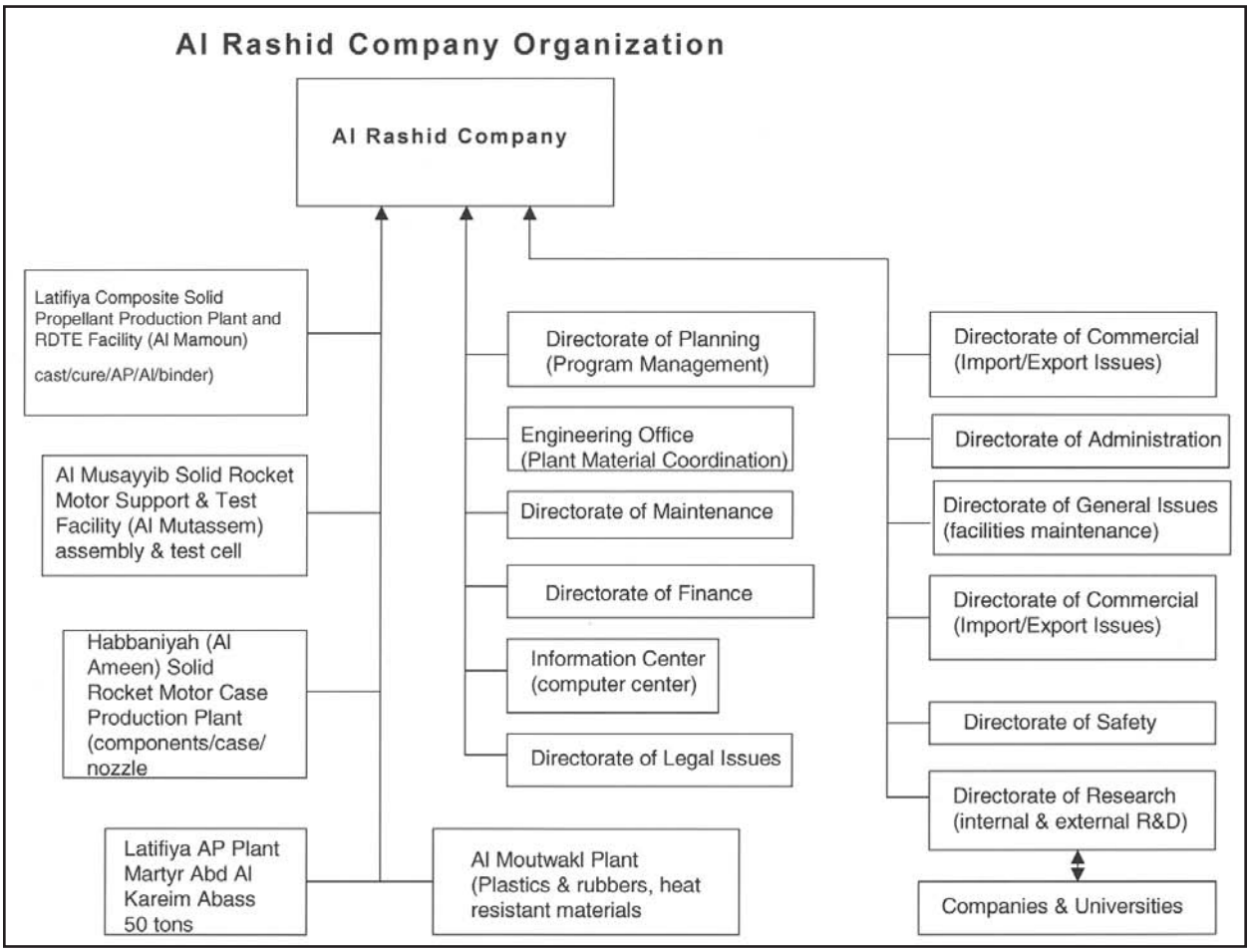

Figure 14. *Al Rashid structure.*

Within the Al Rashid Company, the Al Ma'mun Composite Solid-Propellant Plant at Latifiyyah was the center of composite solid-propellant research and production. Within the complex were facilities for composite propellant mixing, casting, and curing. Motors for existing systems, like the LUNA-M, were reengineered with composite propellant. Motors for new systems, like the Al Fat'h, were also assembled and inspected here. In addition, research and development efforts in the area of composite propellants were conducted at both Ma'mun and Al Kindi.

The Al Musayyib Solid Rocket Motor Support and Test Facility at Al Mutasim contained horizontal rocket motor test cells and motor assembly buildings. All of the Al Rashid associated solid-propellant static tests were conducted at Al Musayyib.

The Al Amin Solid Rocket Motor Case Production Plant at Habbaniyah produced motor casings and nozzles and undertook hydrostatic testing of the motor case. Figure 15 shows an Al-Fat'h motor nozzle.

Figure 15. *Al Fat'h rocket motor nozzle.*

3.6 Al Fat'h Test Launches

ISG has compiled data concerning flight tests for the Al Fat'h missile from various sources shown in Figure 16 .

Al Fat'h Flight Test Launches								
B. Count	Missile No.	Motor No.	Action	Date	Range (km)	Lateral Dev. (km)	Results	Purpose
1	F6		TEST FLT 1	9/1/2000	4	?	F	Motor Perform.
2	F8		TEST FLT 2	10/23/2000	83.4	?	S	Motor Perform.
3	F9		TEST FLT 3	11/18/2001	118??	?	S	to confirm last test (2000???)
4	F??		TEST FLT 4	3/17/2001	117.7	11.5R	S	Motor Perform.
5	F12		TEST FLT 5	3/27/2001	133	10L	S	Motor Perform.
6	F13		TEST FLT 6	4/29/2001	88	34°	F	PRELIM TEST R-40 CONTROLS
7	F14		TEST FLT 7	9/30/2001	7	n/a	F	PRELIM TEST R-40 CONTROLS
8	F17		TEST FLT 8	8/8/2001	161	13.5R	S	Rocket Perform. & Range
9	F18		TEST FLT 9	8/8/2001	6	n/a	F	1st spin mtr test
10	F19		TEST FLT 10	8/22/2001	7	n/a	F	perform. using frontal fins
11	F20		TEST FLT 11	9/6/2001	103	n/a	P.S.	perform. & range with spin motor
12	F21		TEST FLT 12	11/3/2001	90	n/a	P.S.	perform. & range with spin motor
13	F22		TEST FLT 15	12/5/2001	103	20L	S	perform. & range with spin motor
14	F23		TEST FLT 13	11/22/2001	134	13°	S	perform. & range
15	F24		TEST FLT 14	12/5/2001	160.5	13R	S	perform. & range
16	F25		TEST FLT 16	12/5/2001	???	50+	P.S.	perform. & range
17	F26		TEST FLT 17	?????	158	2.4L	S	perform. & range
18	F37	M24	TEST FLT 18	1/26/2002	151	4.2	S	perform. & range
19	F39	M24	TEST FLT 19	3/14/2002	143	?	P.S.	1ST CLUSTER WARHEAD TEST
20	F43		TEST FLT 32	11/25/2002	131	4.4L	S	approval of cluster warhead
21	F46	M55	TEST FLT 20	4/22/2002	147	8°	S	testing warhead fuze
22	F59		TEST FLT 21	9/6/2002	ukn	ukn	F	accuracy & range
23	F60		TEST FLT 22	9/6/2002	ukn	ukn	F	accuracy & range
24	F67	M71	TEST FLT 23	7/22/2002	145	8R	S	accuracy & range
25	F70		TEST FLT 27	9/30/2002	158.2	6R	S	accuracy & range
26	F74	M80	TEST FLT 26	8/24/2002	151.1	13R	S	accuracy & range & warhead
27	F75	M78	TEST FLT 24	8/18/2002	4	n/a	F	accuracy & range & warhead
28	F76	M90	TEST FLT 25	8/22/2002	145	15L	S	accuracy & range
29	F78*	M87	TEST FLT 31	8/22/2002	151.1	ukn	S	approval of rocket
30	F79		TEST FLT 28	9/30/2002	154.4	6.3R	S	accuracy & range
31	F80		TEST FLT 29	9/30/2002	114.6	n/a	F	accuracy & range
32	F84	M90	TEST FLT 30	10/28/2002	147	ukn	S	approval of rocket
Note 1: Apparent transition of date, 9 June or 6 September.								

Figure 16. *Iraqi accounting of Al Fat'h missile testing.*

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Annex D
People

Ra'ad and Muzhir

Beginning before the 1990s, the changes in career of two people, Maj. Gen. Ra'ad Jasim Isma'il Al Adhami and Brig. Gen. Dr. Muzhir Saba' Sadiq al-Tamimi, have been cloaked in mystique and intrigue. They have competed for supremacy on many occasions, one often replacing the other in key technical positions in the Iraqi ballistic missile program after undercutting the others efforts. Dissecting the plot tells much about the relationships within the Iraqi hierarchy and the strong family and religious ties that directly affected the outcome of the efforts to build a successful ballistic missile program.

The first clash came when Muzhir is directed by Husayn Kamil (HK) to review the Rafidiyan project (a conversion of the SA-2 surface-to-air missile to a surface-to-surface role). The report is critical and the project canceled. Ra'ad was fired, and, as a result, Muzhir took control of the responsible establishment, Al Karamah. Ra'ad spent his time fruitlessly at MIC, later supporting the National Monitoring Directorate (NMD) in its role as the Iraqi counterpart of UNSCOM.

With support from Dr Hamid Khalilal-Assawi, Ra'ad designed a 500-mm-diameter missile, which they claimed could maintain Iraq's missile liquid-propellant expertise and infrastructure whilst remaining within the 150-km-range limitation imposed by UNSCR 687. A presentation to HK was successful, and Ra'ad was reinstated as Head of Al-Karamah. Muzhir, being retained as Head of Ibn al Haytham, proposed a competitive design at a 750-mm diameter, which is soon banned by UNSCOM as being too difficult to monitor and capable of being fitted with 2 SA-2 type engines. Undaunted, Muzhir proposed a 600-mm design, which in late 1995 competed with Ra'ad's design in a design review competition. Ra'ad's design was successful, and Muzhir was forced to work on this project under Ra'ad.

Ra'ad Ismail Jasim Isma'il al-Adaml (left) and Muzhir Sabah Sadiq al-Tamimi (right).

This situation did not last long as Muzhir was jailed for 25 months for allegedly importing gyros from Russia (an allegation vigorously denied). Ra'ad continued developing the Samud but could not achieve consistency or reliability.

One of Huwaysh' primary responsibilities when he became head of MIC was to successfully complete the development of the Al Samud ballistic missile. Soon after assuming control of MIC, in an attempt to fix the ballistic missile problems, Huwaysh worked to obtained Muzhir's release from jail. With Ra'ad showing little progress, Huwaysh, who had heard of Muzhir's past experience in this field, appealed to Saddam and obtained his release. Muzhir who on release, had begun working under Huwaysh at MIC, was tasked to review the Al Samud program—his report was unfavorable. After another failed test flight, Huwaysh fired Ra'ad in June 1999, replacing him with Muzhir. Ra'ad, along with Dr Hamid, was transferred to the MIC. Ra'ad spent the remainder of 1999 at MIC before Huwaysh transferred him to head up the Samarra Electronics Plant, the Salah al-Din State Company. On 15th June 2001, Huwaysh accedes to Muzhir's request to replace the 500-mm diameter Al Samud with a 760-mm design,

called the Al Samud II. The first experimental test flight of Al Samud II occurred on 18th August 2001, a surprisingly short time from go-ahead.

The first 10 Al Samud II ballistic missiles were delivered to the Iraqi Army in December 2001.

Drawing dates (August 2000) on designs for a longer range liquid-propellant ballistic missile, both 2- and 5- engine cluster types, suggest that, by OIF, Muzhir might have been well along the road to developing these systems. However, no evidence has been found by ISG that suggests that a development program was instigated.

Nuclear

Keep nuclear scientists together at IAEC
in order to pool their skills and have
them available when needed . . .

Saddam Husayn

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Contents

Annexes

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Key Findings

Iraq Survey Group (ISG) discovered further evidence of the maturity and significance of the pre-1991 Iraqi Nuclear Program but found that Iraq's ability to reconstitute a nuclear weapons program progressively decayed after that date.

- Saddam Husayn ended the nuclear program in 1991 following the Gulf war. ISG found no evidence to suggest concerted efforts to restart the program.

- Although Saddam clearly assigned a high value to the nuclear progress and talent that had been developed up to the 1991 war, the program ended and the intellectual capital decayed in the succeeding years.

Nevertheless, after 1991, Saddam did express his intent to retain the intellectual capital developed during the Iraqi Nuclear Program. Senior Iraqis—several of them from the Regime's inner circle—told ISG they assumed Saddam would restart a nuclear program once UN sanctions ended.

- Saddam indicated that he would develop the weapons necessary to counter any Iranian threat.

Initially, Saddam chose to conceal his nuclear program in its entirety, as he did with Iraq's BW program. Aggressive UN inspections after Desert Storm forced Saddam to admit the existence of the program and destroy or surrender components of the program.

In the wake of Desert Storm, Iraq took steps to conceal key elements of its program and to preserve what it could of the professional capabilities of its nuclear scientific community.

- Baghdad undertook a variety of measures to conceal key elements of its nuclear program from successive UN inspectors, including specific direction by Saddam Husayn to hide and preserve documentation associated with Iraq's nuclear program.

- ISG, for example, uncovered two specific instances in which scientists involved in uranium enrichment kept documents and technology. Although apparently acting on their own, they did so with the belief and anticipation of resuming uranium enrichment efforts in the future.

- Starting around 1992, in a bid to retain the intellectual core of the former weapons program, Baghdad transferred many nuclear scientists to related jobs in the Military Industrial Commission (MIC). The work undertaken by these scientists at the MIC helped them maintain their weapons knowledge base.

As with other WMD areas, Saddam's ambitions in the nuclear area were secondary to his prime objective of ending UN sanctions.

- Iraq, especially after the defection of Husayn Kamil in 1995, sought to persuade the IAEA that Iraq had met the UN's disarmament requirements so sanctions would be lifted.

ISG found a limited number of post-1995 activities that would have aided the reconstitution of the nuclear weapons program once sanctions were lifted.

- The activities of the Iraqi Atomic Energy Commission sustained some talent and limited research with potential relevance to a reconstituted nuclear program.

- Specific projects, with significant development, such as the efforts to build a rail gun and a copper vapor laser could have been useful in a future effort to restart a nuclear weapons program, but ISG found no indications of such purpose. As funding for the MIC and the IAEC increased after the introduction of the Oil-for-Food program, there was some growth in programs that involved former nuclear weapons scientists and engineers.

- The Regime prevented scientists from the former nuclear weapons program from leaving either their jobs or Iraq. Moreover, in the late 1990s, personnel from both MIC and the IAEC received significant pay raises in a bid to retain them, and the Regime undertook new investments in university research in a bid to ensure that Iraq retained technical knowledge.

Evolution of the Nuclear Weapons Program

The Regime and WMD Timeline

For an overview of Iraqi WMD programs and policy choices, readers should consult the Regime Strategy and WMD Timeline chart, enclosed as a separate foldout and in tabular form at the back of Volume I. Covering the period from 1980-2003, the timeline shows specific events bearing on the Regime's efforts in the BW, CW, delivery systems, and nuclear realms and their chronological relationship with political and military developments that had direct bearing on the Regime's policy choices.

Readers should also be aware that, at the conclusion of each volume of text, we have also included foldout summary charts that relate inflection points—critical turning points in the Regime's WMD policymaking—to particular events/initiatives/decisions the Regime took with respect to specific WMD programs. Inflection points are marked in the margins of the body of the text with a gray triangle.

The Early Years: Ambition

Saddam demonstrated his commitment to obtain a nuclear weapon over two decades. Saddam's close association with the Iraqi Atomic Energy Commission (IAEC) stems from his service as Vice President of the Republic from 1968 until 1979 when he became President of Iraq. From 1973 to 1979, he also served as President of the IAEC and sponsored its acquisition of foreign-supplied facilities with which to support a nuclear weapons program.

In 1968, Iraq commissioned a Russian supplied IRT-2000 research reactor and commissioned a number of other facilities that could be used for radioisotope production at the Tuwaitha Nuclear Research Center, home of the IAEC. In the 1970s, through contracts with French and Italian firms, the IAEC built facilities at Tuwaitha that, if operational, could have allowed Iraq to attempt to produce plutonium for a weapons program. ***The Israeli destruction of the Tammuz 1 (Osirak) research reactor on 7 June 1981 and Iraq's subsequent failure to replace or rebuild it compelled the Iraqis to pursue a more clandestine uranium enrichment program for a nuclear weapon by the mid-1980s.***

Between 1979 and 1982, Iraq bought large quantities of uranium in various forms including yellowcake and uranium dioxide from several countries. Some of the purchases were reported to the IAEA and some were not. Iraq's uranium purchases are detailed in its CAFCD in 2002 and in other, earlier disclosures.

Not long after the start of the Iraq-Iran war, Iraq began to formally pursue uranium enrichment. In January 1982, the Office of Studies and Development (OSD) was established in the IAEC to conduct research and development in uranium enrichment. The staff of OSD was drawn largely from the staff of IAEC and numbered no more than several hundred. In late 1982, the IAEC was restructured and OSD became known as Office 3000.

During the Iraq-Iran war, Iraq studied a variety of uranium enrichment techniques. It was not until near the last year of the war in the late 1980s that Iraq began to make decisions and take serious steps to develop a nuclear infrastructure.

In April 1987, the IAEC created a group structure that assigned responsibility for gaseous diffusion research projects to Group 1, EMIS research and development to Group 2, and support activities to Group 3 in the Office of Studies and Development, or Office 3000.

Also in April 1987 a program, codenamed the Al-Husayn project (HP), was formed under Husayn Kamil, supervisor of the State Organization for Technical Industries at the time, to study the steps required to start a nuclear weapons program in Iraq. The finished report outlined a range of projects and served as the basis of a formally constituted nuclear weapons program. In November 1987, the project team was transferred to the IAEC and in April 1988 became Group 4 in Office 3000. The program was implemented in June 1987 and construction began on a nuclear weapon research, development, and production complex at Al Athir in August 1988.

In August 1987, Group 1 formally left the IAEC and Tuwaitha to act independently as the Engineering Design Directorate (EDD) in the Ar Rashidiyah District of Baghdad. At that time the EDD began to develop centrifuge enrichment technology and throughout its existence was directly responsible to Husayn Kamil.

Nearly all avenues of uranium enrichment were considered, but by late 1987 Iraq began construction of a large electromagnetic isotope separation (EMIS) plant at Tarmiya. To support the large investment in EMIS technology, a network of facilities was created to concentrate uranium, convert uranium to feed materials, fabricate EMIS equipment, and chemically recover product.

As the Iraq-Iran war drew to a close, further changes were made in the Iraqi Nuclear Program structure that would ultimately place the nuclear weapons program under Husayn Kamil. In May 1988, when the Ministry of Industry and Military Industrialization (MIMI) was officially established, EDD, renamed the Engineering Design Center (EDC), became one of the institutions of the Military Industrialization Commission (MIC), under MIMI. In November 1988, Office 3000 (Groups 2, 3, and 4) was transferred to the MIMI and in January 1989 officially given the name Petrochemical Project 3 (PC-3) under Dr. Ja'far Diya' Ja'far. Husayn Kamil, Director of MIC and MIMI, assumed control of the Iraqi Nuclear Program.

In August 1988, German engineers traveled to Baghdad and presented European centrifuge design data that EDC immediately copied to advance its otherwise slow progress in developing centrifuge enrichment. In the years before the 1991 Gulf war, several more German engineers became involved, and centrifuge design documents based on technology developed for the European enrichment consortium URENCO were transferred to EDC. Contracts were signed with a number of European firms to acquire key component manufacturing technology and critical equipment for the centrifuge program.

After the invasion of Kuwait and the UN economic embargo, Iraq initiated an accelerated, or "crash program." to produce a nuclear weapon that called for the diversion of IAEA-safeguarded research reactor fuel at Tuwaitha. Iraq planned to further enrich some research reactor fuels using an envisioned 50-machine centrifuge cascade to produce enough weapon-grade uranium for one nuclear weapon. There were numerous obstacles—such as deficiencies in cascade development, uranium recovery capability, and weapons design and development—that prevented the Iraqis from succeeding.

At the time the program ended in early 1991, the Iraqi Nuclear Program (INP) had several thousand personnel, and Iraq was commissioning EMIS equipment at Tarmiya and producing micrograms of enriched uranium. The centrifuge enrichment program was successfully operating a single machine in a test stand and building facilities for a small enrichment cascade. The Iraqis were working on a first-generation nuclear weapon design, which they intended to make into a device deliverable by missile.

Decline (1991-96)

Following the invasion of Kuwait, nearly all of the key nuclear facilities—those involved in the processing of nuclear material or weapons research—were bombed during Desert Storm. Many of the facilities located at Tuwaitha were devastated, and the EMIS enrichment plants at Tarmiya and Ash Sharqat were largely destroyed. Iraq's yellowcake recovery plant at Al-Qa'im and feed material production plant at Mosul (Al Jazira) also were bombed during the war. Al-Athir—a high-explosives testing site revealed after the war to be Iraq's planned nuclear weapons development and assembly site—was also damaged. Iraq' s centrifuge research and development site at Rashdiya and the planned centrifuge production and operations site at Al Furat were neither found nor targeted in the 1991 war, but industrial sites, found after the war to be supporting nuclear weapons efforts, were attacked and damaged.

The Iraqis first chose not to disclose the extent of their clandestine nuclear program in their April 1991 declaration. As part of a denial and deception effort at the end of May 1991, Kamil issued orders to collect all documents and equipment indicating

Non-Proliferation Treaty violations. Equipment and documentation were moved to a variety of locations to hide program elements from the IAEA. Iraqi researchers were instructed by their managers to dispose of their laboratories, some of which were then set up in universities and institutes. In addition, Kamil ordered that at least one set of all nuclear-related documents and some equipment be retained by a senior scientist.

It was not until the Iraqis were confronted with evidence and IAEA successfully seized EMIS components in June/July 1991 that the Iraqis admitted to the large enrichment program. ***Large quantities of EMIS equipment were unburied and delivered to IAEA for destruction*** later that year.

Even though the existence of their centrifuge enrichment program was known before 1991, the Iraqis did not fully declare its extent and maintained that it was only a limited research and development activity located at Tuwaitha, rather than Ar Rashidiyah. In 1991 the Iraqis also declared the planned centrifuge facility at Al Furat as under construction.

- After the seizure of documents pertaining to Iraq's nuclear weapons program in late September 1991, the Iraqis admitted to the existence of the Al Athir. The facility was destroyed by IAEA in April-June 1992.

Starting in 1992, MIC Director Husayn Kamil distributed PC-3 and EDC personnel and work centers around various military research and production facilities. The intention, according to one scientist from the pre-1991 nuclear program, was to keep researchers together in anticipation of a reconstituted nuclear weapon program.

Former PC-3 or EDC personnel working at the Pulse Power Research Center, which became Al Tahadi State Establishment in 1995, created an ion implantation lab with components from former IAEC and PC-3 projects (1994) and a rail gun experiment for air defense, which also used equipment from IAEC and PC-3 (1993-95).

Iraq resisted a more comprehensive disclosure of its nuclear program until after the defection of Husayn Kamil in August 1995, when a large collection of centrifuge and nuclear program documents and equipment was given to UNSCOM and IAEA. From that point onwards, the Iraqis appear to have cooperated and provided more complete information. The centrifuge program appears to have largely been declared, though a full set of documents delivered by German engineers was not supplied to IAEA inspectors.

Efforts that could preserve the progress and talent that had been developed up to the 1991 war included keeping the nuclear cadre engaged in a variety of projects, such as rebuilding of Iraq's infrastructure. However, the nuclear program was ended and the intellectual capital decayed in the succeeding years. The economy had declined, and the talent had been focused on rebuilding the country as well as other military priorities. In some cases, extraordinary measures had to be taken to retain scientists, such as restricting foreign travel or seeking other jobs.

Recovery and Transition (1996-2002)

Iraq collaborated with the International Atomic Energy Agency (IAEA) to produce a series of Full, Final, and Complete Disclosure (FFCD) statements, including a "final" presented to the IAEA in September 1996, which reported its review findings to the UN Security Council in October 1997. The IAEA concluded that it had a technically coherent picture of the pre-1999 nuclear weapons program, although it was troubled by the absence of centrifuge program documentation and there were gaps in knowledge about nuclear weapon design and development activities and the role of foreign assistance—the latter point also a reference to a pre-1991 offer by a representative of Pakistan's A. Q. Khan to assist Iraq in developing nuclear weapons.

'Abd-al-Tawab 'Abdallah Al Mullah Huwaysh became director of the MIC in 1997 and appeared to bear no loyalty to the former nuclear program and IAEC personnel. He standardized salaries, eliminating the preferential pay differential given former PC-3 workers, and instituted measures to emphasize and monitor performance throughout MIC.

With the influx of funds from the Oil For Food (OFF) Program and later the suspension of cooperation with UNSCOM, Saddam's attention began to return to the former employees of the Iraqi Nuclear Program. In the late 1990s, raises in salaries were given to the employees of both the MIC and the IAEC. New programs were initiated, which would employ the talent of former Iraqi Nuclear Program employees, and both the MIC and IAEC expanded. Joint programs with universities were started not only to support a deteriorating university system but also to encourage involvement in MIC and IAEC efforts, offering the opportunity to pass knowledge on to new generations of scientists.

After 1998, interest by Saddam in air defense stimulated projects involving a former nuclear researcher—including one project that had the prospect of supporting a renewed nuclear weapons effort. The IAEC started a rail gun project in 1999, and the MIC was sponsoring a rail gun project at Al Tahadi in 2000. Both projects, and other air defense projects at IAEC, had poor prospects for success as weapons. The IAEC rail gun effort—led by the former head of the pre-1991 nuclear weapons design and development effort, Khalid Ibrahim Sa'id—could, with significant further development, be useful for future nuclear weapons design and development research.

New departments were established in the Physics Department of the IAEC. While primarily supporting the IAEC rail gun project, a Technical Research Branch—with laboratories for high-speed imaging, flash X-ray, impact studies, electronics, and computing—was established in 2001 in newly created laboratories outside the gates of Tuwaitha. A new laser division was created in 1999, and other departments were modernized through purchases of new equipment. Efforts were made to expand ties to universities and train more students at IAEC. Procurements were made through MIC to improve the equipment at IAEC's machine tool workshop.

Miscalculation (2002-2003)

In the year prior to Operation Iraqi Freedom (OIF), MIC undertook improvements to technology in several areas that could have been applied to a renewed centrifuge program for uranium enrichment. These dual-use technologies included projects to acquire a magnet production line at Al Tahadi, carbon fiber filament winding equipment for missile fabrication at al Karama, and the creation of a new Department of Rotating Machinery at Ibn Yunis. All of these projects were created to improve specific military or commercial products, but the technologies could have help support a centrifuge development project. ***ISG, however, has uncovered no indication that Iraq had resumed fissile material or nuclear weapon research and development activities since 1991.***

Results of ISG's Investigation on Nuclear Issues

Iraq did not possess a nuclear device, nor had it tried to reconstitute a capability to produce nuclear weapons after 1991.

ISG has uncovered no information to support allegations of Iraqi pursuit of uranium from abroad in the post-Operation Desert Storm era.

- In the late 1970s and early 1980s, Iraq had an aggressive program to acquire uranium. Iraq's known inventory of safeguarded uranium has been accounted for by the IAEA and Coalition in June 2004. These issues are described in detail in the uranium pursuits section of this paper.

Iraq did not reconstitute its indigenous ability to produce yellowcake. As a result of Desert Storm and IAEA inspection efforts, Iraq's indigenous yellowcake production capability appears to have been eliminated. Bomb damage in 1991 destroyed the uranium extraction facility at the Al Qaim Superphosphate Fertilizer Plant. During the years of intrusive inspections, the IAEA also closed and sealed the Abu Skhair mine to curtail Iraq's secondary pilot plant production capability for acquiring uranium.

- ISG also investigated the former nuclear facility at Tarmiya but found no indicators that the processes being developed there had produced more than a few kilograms of uranium-bearing wastes as a byproduct of phosphoric acid purification.

- These issues also are further described in the uranium pursuits section of this paper.

Post-1991, Iraq had neither rebuilt any capability to convert uranium ore into a form suitable for enrichment nor reestablished other chemical processes related to handling fissile material for a weapons program. Prior to the 1991 war, Iraq had established uranium conversion and feed material capabilities at the Tuwaitha Nuclear Research Center—Baghdad's premier nuclear center—as well as a feed material plant near Mosul called Al-Jazira. Iraq also was establishing chemical processes at Tarmiya, and Al-Sharqat—its two primary sites for uranium enrichment using the electromagnetic isotope separation (EMIS) technique. Baghdad also planned to produce feed materials for its centrifuge program at its main centrifuge research site Rashidiyah and planned a pilot plant at Al Furat. Uranium metal production planned for the pre-1991 program was planned for the Al-Athir nuclear weapons assembly facility. These issues are described in the EMIS and uranium conversion sections of this paper.

Available evidence leads ISG to judge that Iraq's development of gas centrifuges for uranium enrichment essentially ended in 1991. Prior to 1991, gas centrifuge technology was one of the primary methods being pursued for uranium enrichment, with emphasis being placed on carbon-fiber composite centrifuge rotors.

- According to Iraq's disclosures to IAEA, ISG interviews and documentary evidence, Iraq's centrifuge program by June 1990 had built—with foreign assistance—two magnetic-bearing centrifuges, one of which was tested with uranium hexafluoride (UF_6) feed. Two oil-bearing centrifuges had also been built by the Iraqis as of June 1989.

- ISG believes a reconstituted program for the purpose of producing material for nuclear weapons would have required redevelopment and testing of centrifuge manufacturing technology, the manufacture of thousands of machines required for a production plant, effort to gain experience in enrichment operations, and production of metric-ton quantities of uranium hexafluoride (UF_6) feed. However, the initial research and development stages might use only a single centrifuge.

- Former Presidential Scientific Advisor Amir Hamudi Hasan al-Sadi stated that he neither received nor issued orders to resume any centrifuge-related work and could not have done so because the war had destroyed the equipment and facilities.

- The head of design implementation in the former centrifuge program, Faris 'Abd Al 'Aziz Al Samarra'i, did not believe that there was a reconstituted nuclear weapons program in Iraq after 1991. He stated that he did not believe that the universities

had the resources or ability to undertake weapon-related research. Since 1992, Dr. Faris had worked for MIC, in Studies and Planning, and as Director General of the Al-Shaheen Company since 1996 and of the al Samud State Company since 2002.

- Jamal Ja'far, the designer of the pre-1991 magnetic centrifuge program, stated in an interview that he also did not believe that it was possible, given the conditions in Iraq in 2002, to reconstitute such a complicated and serious effort.

- Additional details on ISG's investigation into centrifuge-related issues can be found in sections dealing with aluminum tubes, carbon fiber, flow forming, magnet production, potential centrifuge-related facilities, and rotating machinery.

ISG also judges that Iraq continued work on none of the many other uranium enrichment programs explored or developed prior to 1991, such as EMIS or lasers. However, many of the former EMIS engineers and scientists continued to work for either the Iraqi Atomic Energy Commission (IAEC) or the Military Industrialization Commission (MIC) in roles that could preserve their technical skills.

- Since Operation Iraqi Freedom, significant looting and damage have occurred at most of the dual-use manufacturing facilities that supported the pre-1991 EMIS program. ISG has not been able to confirm that the Iraqi Regime attempted to preserve the EMIS technology, although one scientist with this pre-1991 program kept documents and components that would have been useful to restarting such an effort.

- Additional details can be found in the EMIS and Laser Research sections of this report.

It does not appear that Iraq took steps to advance its pre-1991 work in nuclear weapons design and development. ISG has not identified a materials research and fissile component manufacturing capability that would be required to reconstitute a nuclear weapons program. Working with molten highly enriched uranium requires special consideration for criticality during the melting and solidification process. ISG found no evidence that Iraq had acquired or developed the technology dealing with casting and machining issues of highly enriched uranium.

- While ISG has not identified any explosive lens development effort in Iraq that was associated with a renewed nuclear weapons program, we do believe that the Al Quds Company—a MIC establishment created in 2002—had a technical department, which built a facility capable of conducting research. ***Such a facility appears well suited for types of explosives research that could be applicable to conventional military and nuclear weapons research.***

- ISG obtained evidence from recovered documents and from debriefings of Iraqi scientists that Iraq utilized high-speed switches—like those of potential interest for nuclear weapons development—in support of rail-gun projects that we believe were intended for air defense. ***ISG has found no links between Iraq's interest in special high-speed switches after 1991 and a nuclear weapons program.***

- ***ISG also was not able uncover indications that Iraq had resumed any work related to neutron initiators/generators for a renewed weapons program.*** The only neutron generation capability found by ISG pertained to known non-weapons-related research under way at the IAEC at Tuwaitha.

- These activities are described in further detail in Potential Weapons Development Issues, IAEC Modernization, and Rail Gun portions of this report.

ISG has uncovered two instances in which scientists linked to Iraq's pre-1991 uranium enrichment programs kept documentation and technology in anticipation of renewing these efforts—actions that they contend were officially sanctioned.

- A former engineer in the pre-1991 EMIS program claimed he was told by the head of MIC in 1997 to continue his work with ion implantation at his Al Tahaddi lab as a way to preserve EMIS technology.

- The former head of Iraq's pre-1991 centrifuge program also retained prohibited documents and components in apparent violation of the Regime's directives. Though this activity was isolated, it also had the potential to contribute to a possible restart of Iraq's uranium enrichment programs.

- Additional details on the disclosures of these two former enrichment officials can be found in the section of the report concerning Hidden Enrichment Technology.

Furthermore, although all of the officials interviewed by ISG indicated Iraq had ended its pursuit of nuclear weapons in 1991, some suggested Saddam remained interested in reconstitution of the nuclear program after sanctions were lifted. Specific details concerning Saddam's continued intent to develop weapons of mass destruction can be found in the section of this report concerning Regime Strategic Intent.

Consistent with Saddam's nuclear ambitions, starting around 1992, Iraq directed scientific expertise to several Iraqi establishments. This action would be consistent with either preserving knowledge for the eventual reestablishment of the nuclear weapon program or with simply utilizing Iraq's technical expertise in areas where it was most needed. In either case, some of the work performed by these former PC-3 scientists inherently preserved some capabilities that would be needed for a reconstituted nuclear weapon program. Details on these activities can be found in the sections of the report concerning IAEC Modernization, University Programs, and Migration of PC-3 Capabilities.

Investigation Into Uranium Pursuits and Indigenous Production Capabilities

Foreign Pursuits

ISG has not found evidence to show that Iraq sought uranium from abroad after 1991 or renewed indigenous production of such material—activities that we believe would have constituted an Iraqi effort to reconstitute a nuclear weapons program. As part of its investigation, ISG sought information from prominent figures such as Ja'far Diya' Ja'far—the head of the pre-1991 nuclear weapons program.

- According to Ja'far, the Iraqi government did not purchase uranium from abroad following its acquisition of yellowcake from Niger in 1981. However, Iraq also purchased uranium dioxide from Brazil in 1982. Iraq declared neither the Brazilian purchase nor one of the Niger purchases to the IAEA—demonstrating that the Iraqi Regime was willing to pursue uranium illicitly.

Regarding specific allegations of uranium pursuits from Niger, Ja'far claims that after 1998 Iraq had only two contacts with Niamey—neither of which involved uranium. Ja'far acknowledged that Iraq's Ambassador to the Holy See traveled to Niamey to invite the President of Niger to visit Iraq. He indicated that Baghdad hoped that the Nigerian President would agree to the visit as he had visited Libya despite sanctions being levied on Tripoli. Former Iraqi Ambassador to the Holy See Wissam Zahawie has publicly provided a similar account.

- Ja'far claims a second contact between Iraq and Niger occurred when a Nigerian minister visited Baghdad around 2001 to request assistance in obtaining petroleum products to alleviate Niger's economic problems. During the negotiations for this contract, the Nigerians did not offer any kind of payment or other *quid pro quo*, including offering to provide Iraq with uranium ore, other than cash in exchange for petroleum.

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Embassy of the Republic of
IRAQ
Nairobi

Embassy of the Republic of
IRAQ
Nairobi

Confidential

No. 7
Dated May 20, 2001

Foreign Affairs Ministry – Ministry Office – Research and Analysis information office /2
Subject / Uranium Material

Enclosed is the report made by a friend from Uganda, Abdul Jamal Abdulnasser, (Bika) about getting uranium and other important metals from his friend in Congo. He told us that he is ready to supply Iraq with these metals if Iraq wants them and it can be done without implicating Iraq. After we checked them, we told him we don't deal with these materials and we explained to him the circumstances of Iraq and the imposed sanctions, and that Iraq is not concerned about these matters right now. He said that he will do his best to help Iraq and Iraq's regime for Jihad together against our enemy, and he considers supporting the power of Iraq to be his participation which is the power for all Muslims, and he feels that his duties are to support and strengthen that power.

Please consider. He kept two samples of uranium and coltat. "A list of elements he offered" Comrad Please give me your opinion - my regards

Attachments Stated above	Rafiq Abdl Lateef (Comrade) send a copy of the letter and a copy of the attachment to D-5 to get his opinion) //illegible signature// July 28 (1-1)	//illegible signature// M.D.BTM/2 May 20
Recorded 3/3	Confidential	

May 20. P.O.BOX 49213, Tel 581142 FAX 580267

Figure 1. *Letter rejecting opportunity to purchase uranium.*

- ISG recovered a copy of a crude oil contract dated 26 June 2001 that, although unsigned, appears to support this arrangement.

So far, ISG has found only one offer of uranium to Baghdad since 1991—an approach Iraq appears to have turned down. In mid-May 2003, an ISG team found an Iraqi Embassy document in the Iraqi Intelligence Service (IIS) headquarters related to an offer to sell yellowcake to Iraq. The document reveals that a Ugandan businessman approached the Iraqis with an offer to sell uranium, reportedly from the Congo. The Iraqi Embassy in Nairobi—in reporting this matter back to Baghdad on 20 May 2001—indicated it told the Ugandan that Iraq does not deal with these materials, explained the circumstances of sanctions, and said that Baghdad was not concerned about these matters right now. Figure 1 is the translation of this document.

Indigenous Production Capabilities

As a result of Desert Storm and IAEA inspection efforts, Iraq's indigenous yellowcake production capability appears to have been eliminated. ISG has uncovered no indicator Iraq had reconstituted production processes to refine uranium or produce yellowcake on a scale needed for a weapons program.

- Iraq's main plant for yellowcake production prior to 1991 was at Al-Qa'im. The plant was designed, erected, and commissioned by Mechim Company of Belgium during the period 1982 to 1984. Using phosphate ore from the Akashat mine and the Prayon process, the first batch of yellowcake was delivered to the IAEC in December 1985 with approximately 168 tons delivered through 1991.

- Bomb damage in 1991 destroyed the uranium extraction facility at the Al-Qa'im Superphosphate Fertilizer Plant. In 1991, inspectors found that Al-Qa'im had been heavily damaged in the war and the structure was unsafe. Visits to the site in interim years did not reveal any attempt to reestablish the plant to produce yellowcake.

Figure 2. *Al Qaim uranium extraction facility destroyed.*

Figure 3. *Graphite furnace (top left); mixer-settlers (top right); atomic absorption-flame emission spectrometer (bottom left); gas chromatography (bottom right).*

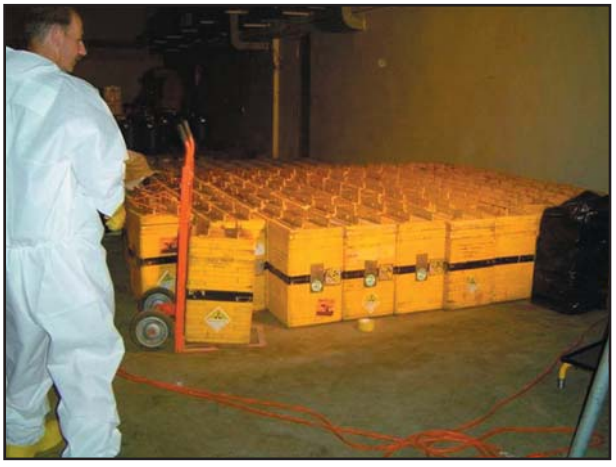

Figure 4. *Monitoring containers of "yellowcake."*

- During the years of intrusive inspections, the IAEA also closed and sealed the Abu Skhair mine to curtail Iraq's secondary pilot plant production capability for acquiring uranium. A year before the closure of the Abu-Sha'ir mine under IAEA supervision in 1993, the processing plant was converted to produce "Alum" from kaolin ore. Subsequent visits by UNSCOM/IAEA continued to report inoperability of the mine. The operation established at Abu-Sha'ir in September 1988 produced 800 tons of ore, 10 tons of which were delivered to a pilot plant at the Geological Survey State Enterprise (GSSE) prior to 1991. Despite this effort, only 0.5 kg of yellowcake was obtained.

- Ja'far also claims that Iraq did not attempt to build another yellowcake production plant after 1991 (see Figure 2).

In May 2003, coalition forces visited the former yellowcake extraction plant at Al-Qaim and discovered 16 drums of yellowcake and radioactive waste—materials we believe were associated with the pre-1991 nuclear weapons program. These drums were transferred in late June 2003 to the yellowcake storage facility located at Tuwaitha. There is no evidence that this material had been produced after Desert Storm

ISG also investigated the Ibn-Sina' Facility—which in 1991 was part of Iraq's EMIS uranium enrichment program—but found no indicators that the chemical processes being developed there had produced more than a few kilograms of uranium-bearing wastes as a byproduct of phosphoric acid purification. ISG believes that the Ibn-Sina'—which concentrated much of the chemical engineering staff from the former PC-3 nuclear weapons program—would most likely have been involved in an effort to reestablish a uranium recovery capability, had such an effort been under way.

Iraq's Known Uranium Holdings

Known Iraqi uranium holdings have been accounted for by the Coalition and the IAEA. In June 2004, a joint IAEA and Coalition team verified the inventory of Iraqi uranium compounds—an inventory comprising both imported material and that indigenously produced prior to 1991 (see figure 4).

- During the 1970s and early 1980s, Iraq bought uranium in various forms from the international market. These materials included about 486 tons of yellowcake, 33,470 kg of "natural" uranium dioxide, 1,767 kg of "low-enriched" uranium dioxide (2.6 percent ^{235}U), and 6,005 kg of "depleted" uranium dioxide from Portugal, Italy, Niger, and Brazil.

Prior to 1991, Iraq also acquired highly enriched uranium for its research reactors from France and Russia—material that was removed from Iraq following the 1991 Gulf war. Following the Husayn Kamil defection in 1995, Iraq admitted that in 1991 it had intended to use this highly enriched fuel as part of a "crash program" to develop a nuclear weapon (see Table 1).

Table 1
Declared Iraqi International Uranium Purchases

Country	Organization/ Company	Time-frame	Uranium Form	Amount	Comment
Portugal	Emprese National de uranio EP	20 Jun 1980	"Yellowcake"	138.098 tons (uranium content approximately 103 tons)	IAEA notified through "ICR" report (29 Jun 80) (not subject to safeguards according to INFCIRC/153 corrected.)
		17 May 1982	"Yellowcake"	148.348 tons (uranium content approximately 110 tons)	No IAEA notification (not subject to safeguards according to INFCIRC/153 corrected.)
		31 May 1982			
		20 Jun 1982			
Italy	SNIA-TECHINT through CNEN	12 Dec 1979	"Depleted" uranium dioxide	6,005 kg	Under IAEA safeguards
		12 Dec 1979	"Natural" uranium dioxide	4,006 kg	
		12 Dec 1979	"Natural" uranium dioxide (pellets & fuel rods)	500 kg	
		18 May 1982	"Low-Enriched" uranium dioxide (2.6% ^{235}U)	1,767 kg	
Niger	ONAREM (Office National Des Resources Minieres)	08 Feb 1981	"Yellowcake"	(uranium content 199.9 tons)	IAEA notified (not subject to safeguards according to INFCIRC/153 corrected.)
		18 Mar 1981			No IAEA notification (not subject to safeguards according to INFCIRC/153 corrected.)
Brazil	Through CNEN (Commisao Nacional de Energia Nuclear)	Sep 1981	"Natural" uranium dioxide	7,964 kg	No IAEA notification
		Jan 1982	"Natural" uranium dioxide	21,000 kg	

Iraqi Uranium Conversion Program

Iraq's pre-1991 uranium conversion program was established at different sites to produce the necessary uranium compounds for the enrichment, reprocessing, and metallurgy programs to support its pre-1991 nuclear weapons program. Iraq had established much of its uranium conversion basic research and development at Tuwaitha. As processes were developed, they were adapted for production at Tuwaitha and other sites as appropriate (see Figures 5 and 6).

- Iraq produced a variety of uranium compounds to support its pre-1991 nuclear weapons program at a number of facilities, including Tuwaitha, al Jazira, Tarmiya, Ash Sharqat, Rashdiya, and Al Athir. At the time of Desert Storm, Iraq's capabilities to produce uranium compounds/metal varied as noted in Table 2.

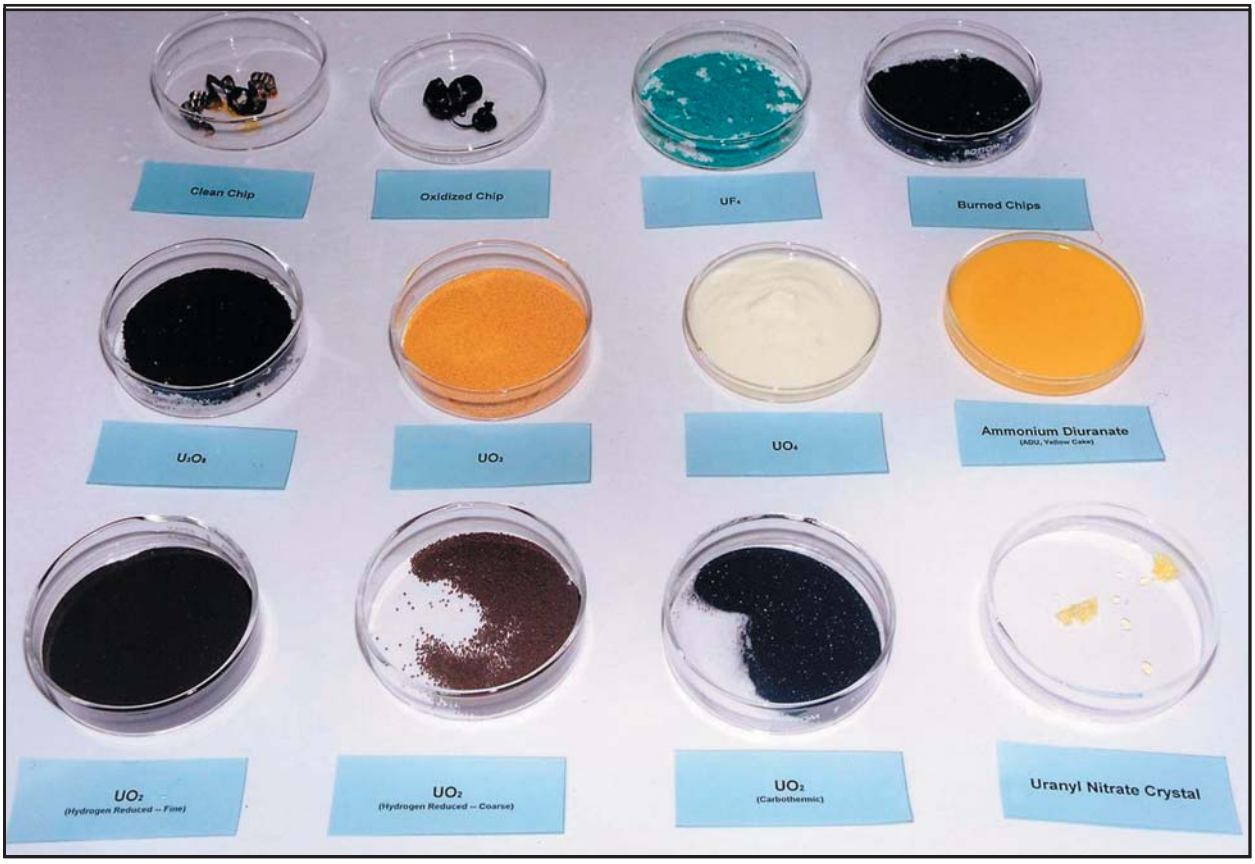

Figure 5. *Forms of uranium.*

Figure 6. *Tuwaitha (Baghdad Nuclear Research Center) (top); Tarmiya (Ibn Sina) uranium recovery facility (bottom).*

Table 2

Iraq Uranium Conversion Program (Pre-Operation Desert Storm)

Site	Bldg	Activity/Capability	Status at ODS
Tuwaitha	9	Reprocessing of irradiated fuel	Operational
	10	Uranium purification	Operational
	15B	UO_2 to UCl_4 lab production for EMIS; UF_4 to U metal preparation experiments; UF_4 and UF_6 production & lab scale preparation	Operational
	22	Reprocessing	Operational
	38 (G1 wing)	UF_4 production	Operational
	64	Uranyl nitrate to U metal; UO_2 to UF_4 to U metal	Operational
	73A&B	UF_4 to U metal production; U metal purification; UF_4 preparation	Operational
	73A	Dissolution of U pellets & fuel; nuclear-grade UO_2 conversion.	Operational
	73B	"Yellowcake" purification & conversion to UO_2 experiments.	Operational
	85	UO_2 to UCl_4 lab & pilot plant production for EMIS; Pilot plant recovery of U from R-100 & R-50 graphite collectors; Purification of UF_6	Operational
	RWTS	Pilot plant U recovery from R-100 & R-50 liners	Operational
Al-Jazira	000	AYC to UO_2 production for EMIS.	Operational
	510	Utilities & storage tanks for Project 212	Operational
	400	UO_2 to UCl_4 production for EMIS	Operational
	401	Utilities for Project 244	Operational
	3 Underground Facilities	Spare parts storage for U program construction phase	Operational
Tarmiya	210	U recovery from R-120 (nongraphite)	Precommissioning
	220	U recovery from R-120 (graphite)	Incomplete
	230	Recovered U to Ucl_4 (nongraphite)	Incomplete
	240	Lab support for Project 266	
	265	Pilot scale U recovery from R-120 (graphite & nongraphite)	Operational
Al-Sharqat	350	Chemical recovery for natural U from components of R120	80% constructed; 60% checked out
	360	U recovery (HEU & depleted U) from R120 &R60 collectors	85% constructed; 50% checked out
	370	U recovery from R60 collector components	80% constructed; 60% checked out
Rashidiya	Hall C	Lab scale UF_6 preparation & purification; UF_4 production	
	9	UF_6 and UF_4 R&D	
	10	UF_6 and UF_4 R&D; UF_6 purification	
	22	UF_6 production	Operational

Table 2

Iraq Uranium Conversion Program (Pre-Operation Desert Storm) *continued*

Site	Bldg	Activity/Capability	Status at ODS
Al-Atheer	6830	U metallurgy	Incomplete
	6520	U metallurgy	Operational
	6580	U chemistry	50% complete
Al-Rabee		U metallurgy	Transferred to Al-Atheer
References: *Currently Accurate, Full, and Complete Declaration of the Past Iraqi Nuclear Program*, 3 Dec 2002			

As a result of Desert Storm and the UN and IAEA efforts afterwards, many of the Iraqi uranium conversion facilities were destroyed or damaged and the program crippled. Many of the facilities of Tuwaitha, Al-Athir, al Sharqat, Rashidiyah, and Al-Athir were destroyed during Operation Desert Storm or subsequently through IAEA inspections. Table 3 indicates the destruction of facilities at the original sites and by whose action.

As a result of Operation Iraqi Freedom and its aftermath, much of Iraq's residual potential uranium conversion capability was destroyed. ISG site visits to many locations found not only destruction resulting from Operation Iraqi Freedom, but also looting that rendered many facilities inoperable. ISG investigations, including sampling and radiation surveys, during these visits uncovered no indications of nuclear weapons-related activity.

- *Tuwaitha (Baghdad Nuclear Research Center).* ISG conducted a series of visits to Tuwaitha. During these visits, 151 structures were surveyed and cleared, 28 structures judged destroyed, and eight structures deemed hazardous (see figure 7).

- *Al-Athir.* US military forces found Al-Athir abandoned and heavily looted. ISG visited and found no evidence of uranium conversion activities.

- *Al Zahf Al Kabeer (Taji Metallurgy).* ISG visits to Al Zahf Al Kabeer found that all research and production buildings showed extensive evidence of looting. They found no evidence of uranium metal production or weapon component production and received no positive readings from radiation surveys.

- *Al Raya.* ISG visits to Al Raya found extensive bomb damage and widespread looting. They found no evidence of uranium metal production or weapon component production and received no positive readings from radiation surveys.

- *Ibn Sina (Tarmiya).* An ISG visit to Ibn Sina found the facility to be closed since major ground combat operations. The facility had been subject to some looting and was apparently in the process of restoring operations. No indicators or evidence of WMD activity was found (see Figure 8).

- Exceptions to the general destruction and looting were Al Amal and Al Salaam. Al Amal was active 24 hours a day, seven days a week to support an oil refinery at Basrah. Al Salaam was not damaged but showed evidence of minor looting (see Figures 7 and 8).

Table 3
Iraq's Uranium Conversion Program (Post-Operation Desert Storm Iraqi & UN/IAEA Activities - Facilities)

Site	Bldg	ODS Impact	Iraqi Actions	IAEA Actions
Tuwaitha	9	Destroyed		
	10	Destroyed	Leveled by Iraq	
	15B	Destroyed	Leveled by Iraq	
	22	Destroyed		
	38 (G1 wing)			
	64	Destroyed		
	73A&B	Destroyed	Leveled by Iraq	
	73A	Destroyed	Leveled by Iraq	
	73B	Destroyed	Leveled by Iraq	
	85	Destroyed	Leveled by Iraq	IAEA destruction
	RWTS	Destroyed		
Al-Jazira	000	Destroyed	Leveled by Iraq	
	510	Destroyed		
	400	50% destroyed; 40% equipment destroyed		
	401	Destroyed		
	3 underground Facilities		Closed and sealed	
Tarmiya	210	Partially destroyed		
	220	Not destroyed		
	230	80% destroyed		
	240	Not destroyed		
	265	Not destroyed		
Al-Sharqat	350	Destroyed		
	360	Destroyed		
	370	Destroyed		
Rashidiya	Hall C		Evacuation and/or destruction of significant materials	Transfer and/or destruction of significant materials
	9			
	10			
	22			
Al-Atheer	6830			Destroyed by IAEA
	6520			Destroyed by IAEA
	6580			Destroyed by IAEA
Al-Rabee				

References: Currently Accurate, Full, and Complete Declaration of the Past Iraqi Nuclear Program, 3 Dec 2002.

Figure 7. *Tuwaitha Building 15 area (top left); Tuwaitha Building 15 area (top right); Tuwaitha Building 73 area destroyed (bottom left); Tuwaitha LAMA Facility (Building 22 destroyed) (bottom right).*

Figure 8. *Tarmiya (Ibn Sina) uranium recovery facility.*

Aluminum Tube Investigation

Baghdad's interest in high-strength, high-specification aluminum tubes—dual-use items controlled under Annex 3 of the Ongoing Monitoring and Verification Plan as possible centrifuge rotors—is best explained by its efforts to produce 81-mm rockets. ISG conducted numerous interviews related to Iraq's interest in acquiring these tubes—information that regularly pointed toward similar tubes being used in the Nasser-81 ground-to-ground rocket system.

- Postwar interviews included prominent figures from Iraq's pre-1991 centrifuge effort, including its director, the project manager for rotor manufacture, other former staff, as well as the head of the overall nuclear weapons program. ISG also interviewed numerous officials directly involved in the 81-mm rocket effort and Iraq's Military Industrialization Commission (MIC). None of these officials admitted to any intended end use of the tubes beyond rockets.

Although ISG also uncovered inconsistencies that raise questions about whether high-specification aluminum tubes were really needed for such a rocket program, these discrepancies are not sufficient to show a nuclear end use was planned for the tubes. For example, ISG has found technical drawings that show the 81-mm rocket program had a history of using tubes that appear to have fallen short of the standard demanded in procurement attempts in the years before the war. Iraq also accepted lower-quality, indigenously produced aluminum tubes for 81-mm rockets in the months before the war despite continued foreign procurement attempts for high-specification tubes.

- ISG believes that bureaucratic momentum made it difficult to abandon the perceived need for high-specification tubes from abroad. These foreign pursuits probably also were affected by a lack of sufficient indigenous manufacturing capabilities—an effort Iraq reportedly began only in mid-2002—the high cost of that production, and pressure of the impending war.
- Efforts to press the Iraqis on other inconsistencies in individual recollections on history, production, questionable engineering practices, or accomplishments also did not produce statements to link the tubes to any effort other than 81-mm rockets.

Elements of ISG Investigation

ISG investigated key indicators that suggested a possible centrifuge end use for the tubes—questioning that revealed plausible explanations for use of the tubes in 81-mm rockets, notably:

- Purported high-level interest in aluminum tubes by Saddam and Iraq's Deputy Prime Minister—a potential indicator of a program of national importance, such as a centrifuge program.
- Possible association of Iraqi nuclear entities with the tubes it sought to procure—reporting suggestive of a nuclear end-user.
- Tube characteristics and shipping requirements—reporting that showed the tubes were subject to nuclear controls and seemed to be over specified for conventional rockets.
- Iraqi effort to indigenously manufacture tubes for an 81 mm-rocket program and its continued effort to acquire tubes with higher specifications.
- Alleged Iraqi interest in 84-mm tubes—a size that would have been inconsistent with the 81-mm rocket program.

In the course of this investigation, ISG did not uncover evidence of a program to design or develop an 81-mm aluminum rotor centrifuge. Other sections of ISG nuclear report describe findings concerning equipment and materials that could have supported a renewed centrifuge effort.

Purported High-Level Interest in Aluminum Tubes

ISG has found that high-level Iraqi interest in aluminum tubes appears to have come from efforts to produce 81-mm rockets, rather than a nuclear end use. Multiple reports indicate Dr. Huwaysh was keenly interested in high-strength, high-specification aluminum tubes for rocket production. Dr. Huwaysh attributes his pursuit of 81-mm rockets to the delivery of some launchers to the military shortly after he became the head of MIC in 1997. As a result, Dr. Huwaysh claims he was bound by requests from the Minister of Defense to produce rockets for those launchers—a task he regularly pressed on MIC leadership at quarterly meetings.

- Dr. Huwaysh's advocacy of 81-mm rockets appears to explain why he sought the delivery of items that were probably sample aluminum tubes. In early 2002, Dr. Huwaysh sought two shipments of high-strength aluminum from an Iraqi procurement firm in Syria.

Several Iraqi officials also commented on Saddam's potential interest in rockets. One official indicates Dr. Huwaysh told MIC engineers that Saddam asked him to make 81-mm rockets. But this link between the tubes and Saddam remains uncorroborated, even by Dr. Huwaysh.

- Ja'far Diya' Ja'far, the head of Iraq's pre-1991 nuclear weapons program and most recently a Presidential Science Advisor, has offered somewhat conflicting accounts regarding Saddam's awareness of the aluminum tubes. While discussing 81-mm rockets, Ja'far claimed Saddam was very interested in aerial weapons. Ja'far has also stated, however, this rocket program was unimportant and that work, including procurement, was known only to lower-level officials. Ja'far—whose debriefing accounts have been known to vary—also doubted Saddam understood the technical specifications of the tubes.

Other interest by senior officials in the 81-mm rocket can be traced to around 1984, when Husayn Kamil reportedly approved a proposal to reverse-engineer and build the weapon system. The proposal, made by an Iraqi Army Aviation officer was based on the premise that it was too expensive to continue importing 81-mm rockets from Italy.

Possible Association of Iraqi Nuclear Entities With the Tubes

The limited information found by ISG that ties Iraqi nuclear entities to the tubes also appears related to the 81-mm rocket program. A 6 March 2003 letter from the Iraqi National Monitoring Directorate (NMD) to the IAEA's Iraq Nuclear Verification Office (INVO) notes that the Iraqi Atomic Energy Commission (IAEC) conducted material composition testing on a sample aluminum tube in early 2001. According to that letter given to ISG, the Rashid State Company—one of the entities involved in 81-mm rocket production—obtained the sample tube through the Ahmed Al-Barrak Bureau, an import/export firm in Baghdad.

- The tube tested by the IAEC reportedly measured 900 mm in length and 81 mm in diameter—a size consistent with prewar procurement attempts. The Rashid State Company requested other physical property tests, but the IAEC did not have capabilities to do the work.

A leading Iraqi nuclear expert measured the tubes to answer questions posed by the IAEA, but ISG has found no indication that this represented interest by Iraq in the tubes for centrifuge applications. In the months before the war, Ja'far Diya' Ja'far admits calling on a leading technical figure in the former centrifuge effort, Dr. Faris 'Abd Al-Aziz Al-Samarrai, to measure dimensional variances on several 81-mm rockets. Multiple officials interviewed by ISG confirm Aziz's work for Ja'far to address questions from IAEA inspectors about the tubes.

- Nonetheless, the letter to the IAEA incorrectly claims that measurements of rockets made with the original pre-1991 tubes met the higher specifications for tubes set by the 2000 committee.

Ja'far's study for the IAEA inspectors apparently acknowledged it was possible to make a centrifuge from the tubes, although he thought doing so was impractical. Ja'far thought the IAEA officials agreed with his assessment but notes they did not make a definitive statement on the utility of the tubes for centrifuges. Ja'far thought the size of the rocket tubes would cause the enrichment output to be far lower

than the centrifuge design Iraq had pursued as of 1991. 'Abd Al-Baqi Rashid Shiya, a former Director General of the Rashid State Company and a key figure in the 81-mm rocket program, told ISG that he informally heard that Ja'far and Al-'Aziz determined that the tubes could not be used for centrifuges.

- In his postwar debriefings, Ja'far also opined that using 81-mm rockets as a cover story for a centrifuge program would not have been very useful because Iraq had difficulties importing any goods. Ja'far also told debriefers that developing an indigenous carbon-fiber filament winding capability would have been much more useful if Iraq intended to resume a centrifuge effort.

Dr. Mahdi Shukur Al 'Ubaydi, the head of the pre-1991 centrifuge program, similarly did not consider it reasonable that Iraq could have pursued a centrifuge program based on 81-mm aluminum tubes. Al 'Ubaydi believes that, besides himself, the only Iraqis capable of assessing the suitability of aluminum tubes for centrifuge use were Jamal Ja'far, Dr. Farid Bashir Yusef, and Dr. Makki Kadhim Rashid—the latter two having fled Iraq years before the war. Al 'Ubaydi assessed that no one in Iraq could have redesigned the centrifuge to use an 81-mm aluminum rotor.

- Al 'Ubaydi stated that Iraq was able to quickly develop its pre-1991 centrifuge program because of the raw intelligence of Jamal, Farid, Makki, and himself—an underestimation, we believe, of the contribution of technology, designs, and expertise provided by a few experts from the European uranium enrichment consortium, URENCO. Nonetheless, Al 'Ubaydi stated it still took Iraq 2.5 years to understand the working design it obtained from abroad.

- Al 'Ubaydi assessed that redesigning a centrifuge by scaling it up or down in size would have been a completely different task, and he would have hesitated "a million times" before attempting to do so. Al 'Ubaydi opined that a renewed effort would more likely build on this earlier work with URENCO-type machines and utilize carbon fiber.

- Another official from the former centrifuge program similarly told ISG that Iraq lacked the necessary expertise to design a centrifuge using 81-mm diameter high-strength aluminum tubes. The official noted Iraq's prewar expert in centrifuge modeling left the country around 1996 and now most likely is a university instructor. The same source describes other losses of personnel with one colleague having left to work in private industry while a third moved to a MIC center.

ISG also has not found a nuclear connection that influenced the evolution of the design or tolerances for the 81-mm tubes. According to reporting, 'Arif Kaddur Al-Kubaysi, former al Fatah Director of Engineering Affairs and lead 81-mm rocket designer, freely set the design of the metal parts of the rocket as he saw fit. This reporting claimed no one changed any specifications for the aluminum tube rocket body after 2000—notably not Ja'far Diya' Ja'far, 'Abd-al-Tawab Huwaysh, 'Abd Al-Baqi Rashid Shiya, or Faris 'Abd Al-Aziz Al-Samarrai.

ISG found only one former nuclear official connected—the connection may be coincidental—to the design of the 81-mm rocket. As the former head of al Qa'Qaa', Sinan Rasim Sa'id reportedly was involved in developing propellant for the rocket—one of the alleged underlying causes of the inaccuracy of the weapon. Prior to 1991, reporting indicates Sa'id helped maintain electrical equipment for the electromagnetic isotope separation (EMIS) and centrifuge uranium enrichment efforts.

Tube Characteristics and Shipping Requirements

ISG's investigation into why Iraq sought aluminum tubes with such high specifications before the war—a key factor that raised concerns that the Regime had restarted a centrifuge effort—has uncovered plausible but not always consistent accounts that link the tubes to 81-mm rockets. Multiple officials involved with the Iraqi rocket program claim that the tight specifications on the aluminum tubes were driven by efforts to improve the accuracy of this barrage-type weapon. These sources report that in 2000, Dr. Huwaysh formed a committee to set final rocket specifications and address problems with its accuracy.

Varied Reactions to the Tube Seizure in 2001

ISG has uncovered mixed and sometimes conflicting reactions by Iraqi officials to the June 2001 seizure of high-strength aluminum tubes—items reportedly stopped based on concerns the tubes violated sanctions and nuclear export controls. *Ja'far told debriefers that the seizure did not capture his attention because he thought the tubes simply were stopped as a result of sanctions. He claims he was not aware of any MIC inquiries in the wake of that seizure to suggest the tubes were intended for centrifuge use and deemed foreign government claims in 2002 that the tubes were suitable for centrifuges as insignificant. He also claims he did not become concerned about centrifuge allegations until early 2003 when the issue arose in the United Nations Security Council.*

- *Ja'far's reported efforts to gather information in early 2003 to deal with IAEA inspectors from Faris Aziz and others seem to be the extent of his concerns with the tubes prior to the war. ISG believes that Ja'far is a likely candidate to have known of renewed nuclear work—had any been under way—given his preeminent role as the head of the pre-1991 nuclear weapons program.*

Similarly, the head of Iraq's pre-1991 centrifuge program reportedly had no knowledge of a nuclear connection to the aluminum tubes until the issue surfaced months before Operation Iraqi Freedom. *According to interrogation interviews, he was not part of Ja'far's review for inspectors, and he was not tasked to consider the suitability of the aluminum tubes for centrifuges. Reportedly Al 'Ubaydi said he learned the tubes were destined for a rocket program in late 2002 when Dr. Amir Al-Sa'di, a Presidential Advisor, queried him if the pre-1991 centrifuge program had used aluminum.*

- *Al 'Ubaydi reportedly learned from Jamal Ja'far, a technical expert from the pre-1991 centrifuge program, that aluminum could be used in magnetic-bearing centrifuges—and passed this point to Sa'di.*

Dr. Huwaysh, however, claims he took several actions in the wake of the 2001 seizure—one of many claims he makes that are inconsistent with other debriefing accounts. *Dr. Huwaysh indicates that it was the procurement front company that first informed MIC that the tubes were stopped because of centrifuge concerns. Dr. Huwaysh then claims he asked Al 'Ubaydi to investigate and received word in early 2002 from Hussam Muhammad Amin, the head of Iraq's National Monitoring Directorate that Al 'Ubaydi concluded the tubes could be used for centrifuges. Dr. Huwaysh then claims he ordered 'Abd Al-Baqi Rashid Shiya, then Director General of the Al-Rashid State Company, to find an alternate metal—not subject to nuclear export controls—that would still be strong enough to make the motor cases for the 81-mm rockets.*

- *Dr. Huwaysh adds that he trusted Baqi to change the alloy and did not confirm the order was followed. When shown a copy of a 2003 fax from a procurement company that specified the prohibited alloy, Dr. Huwaysh adamantly claimed it was a mistake, as Baqi would never have disobeyed his order.*

Baqi claims that Dr. Huwaysh did not ask him to make any changes after the capture of the tubes during the summer of 2001, adding that other key rocket program officials would have known of such a modification if it had been ordered. Baqi reportedly heard indirectly that Dr. Huwaysh did not think the tubes were suitable for centrifuges and that news reporting in this regard was mistaken.

- Engineer Abd Al-Baqi Rashid Shiya, then Director General of the al Rashid State Company, led the 17-member committee, supported by his deputy and head of the National Monitoring Directorate (NMD) at al Rashid, Sa'ad Ahmad Mahmud. NMD head Lt. Gen. Husam Amin also participated, ostensibly due to his rocket engineering expertise, as did Arif Kaddori Atawi Al-Kubaysi, the lead engineer for the 81-mm rocket program. (See inset on insights.)

- The committee reportedly completed its work in September 2000, concluding that inconsistencies between rockets resulted in variations in range and accuracy—a problem they chose to address, in part, by reducing mass differences between rockets and components by tightening specifications. The committee also reportedly considered propellant-related problems and quality-control issues.

Comments From the Head of the "2000 Committee"

ISG interviews with 'Abd Al-Baqi Rashid Shiya revealed insights into the thinking of the 2000 Committee, which he led in an attempt to improve the accuracy of the 81-mm rocket. *Baqi claims that the 2000 committee noticed that the engineering drawings for the 81-mm rocket had undergone many ad hoc revisions over the years, changes ostensibly made to ease its manufacture. Baqi told postwar debriefers that one goal of the 2000 committee was to return the 81-mm rocket to its original Italian-based design by setting new specifications for imported tubes—an unrealistic goal given that Iraq had made changes in the late 1980s that affected propellant performance and lifetime.*

According to Baqi, the committee checked all the parts of the rocket and found that unwanted dispersion was caused by problems with the nozzle and the nonalignment of the propellant, nozzle, and motor case—a slightly different cause than the mass differences noted by other officials. *Baqi also described that the committee examined problems with the propellant, manufactured by the Al-Qa' Qaa' State Company, because this would occasionally cause rockets to explode during flight. The committee reportedly concluded these misfirings were caused by pitting of the tubes—probably a reference to corrosion marks caused by improper storage—and problems with the insulator between the propellant and the tube. Baqi also claimed that the launcher was not a significant part of the rocket's scatter problems—a conclusion also reached by the 2000 Committee.*

- *A separate source associated with the rocket program claimed the 81-mm rocket accuracy was adversely impacted by a number of factors—some resulting from its conversion from an air-to-ground into a ground-to-ground system. This source claimed that down-range accuracy problems were caused by a lack of initial velocity, instabilities from the ground launch platform, and insufficient design features that would have produced more spin.*

- *This source also claimed the quality of Iraqi propellant adversely affected the range of the 81-mm rocket. Iraq reportedly modified its 81-mm rocket propellant in 1988 or 1989 when Amir Al-Sa'di, then Director of the MIC, commissioned a group at al Qa' Qaa' to examine why some Italian-made rockets prematurely exploded. The group discovered droplets of nitroglycerine formed on the propellant inside the rocket body, causing the malfunction. By modifying the propellant, Iraq increased rocket shelf life from 1 to roughly 5 years but at the cost of consistent propellant performance that affected accuracy.*

Baqi claims he was not alone on the 2000 committee in questioning why the military wanted the 81-mm rocket, adding that the 107-mm rocket was easier to produce, had fewer parts, and a bigger warhead. *Baqi notes the lead production engineer and Kubaysi as two of the 2000 committee members who shared his views that it was a bad idea for Iraq to make the 81-mm surface-to-surface rocket by attempting to copy the Italian air-to-surface rocket. Baqi claimed many engineers wanted to end the 81-mm rocket program in favor of the 107-mm rockets.*

- *Baqi echoed claims by Dr. Huwaysh that the military apparently wanted the 81-mm rocket because they already had launchers for them. Additionally, Baqi noted quality control was a general problem with the 81-mm rocket program.*

- *Reporting indicated that the 81-mm rocket program should have been canceled because other rockets in Iraq's arsenal were capable of fulfilling its role and posed fewer problems. According to this reporting, the nominal 9.5-kilometer range of the 81-mm rocket could be covered by the 107-mm and 122-mm systems with ranges of 1-8 kilometers and 5-20 kilometers, respectively. According to reporting, many military officers were opposed to the 81-mm rocket system, but they allegedly were overruled by more senior leadership. According to reporting, the 81-mm rocket suffered about twice as much scatter as the 122-mm rockets Iraq produced.*

Nearly all critical linear dimensions and related tolerance specifications that raised prewar concerns over possible centrifuge end use can be linked to decisions reportedly made by the 2000 Committee for rockets. While participating in the work of the 2000 Committee, multiple officials indicate the lead design engineer tightened the inner and outer diameter specifications for imported tubes. In his interviews with ISG, the lead design engineer noted that the 2000 Committee decided that the rocket body mass could vary by only 30 grams—a tight requirement that led to the setting of diameter specifications used in Iraqi procurement attempts since April 2002 –the same values Iraq's NMD declared to the IAEA in the 6 March 2003 letter. (see Table 4.)

- The lead design engineer also reportedly sought to reduce the total allowed mass variation between rockets to 300 grams out of 8.5 kilogram total weight, with only 150 grams allocated to differences stemming from metal parts. Reportedly, pressure testing confirmed that trimming wall mass from the rocket tubes did not adversely affect the strength of the tube.

Reporting indicates the shipping requirements originated from recommendations by Dr. Sami Ibrahim of the Baghdad University of Technology, who investigated why the aluminum tubes, purchased from Germany in the 1980s for the 81-mm rocket program, corroded when stored outdoors at Tho Al-Fiqar.

- Ibrahim concluded that the unanodized German tubes corroded from a galvanic reaction made possible by stacking the tubes horizontally in direct contact with each other and outdoors. Ibrahim reportedly noticed other unanodized 7075 alloy aluminum tubes also stored outdoors since 1989 at Tho Al-Fiqar, a flow-forming facility. These tubes were stored upright and separated from each other with nylon mesh—factors that influenced his recommendations on how to prevent tube corrosion.

Baqi's requirements seem to have grown out of a desire to avoid angering Dr. Huwaysh, who reportedly was upset when he saw the corroded tubes at Tho Al-Fiqar during a visit in 1998. Iraq also took a further precaution of reanodizing aluminum parts after machining to ensure that no further corrosion would occur.

Tho Al-Fiqar also seems to have set other specifications for the rocket program that were not directly addressed by the 2000 Committee in its procurement specification document. According to a former official in the 81-mm rocket program, the Tho Al-Fiqar specifications document was prepared to assist procurement officials in acquiring high-strength aluminum tubes. In that document, the lead production engineer reportedly set an artificially tight specification of 0.05 mm for eccentricity—one of the properties related to uniform tube wall thickness. Tho Al-Fiqar officials insisted on the specification—twice as tight as the 0.1 mm reportedly actually needed—to ensure that imported tubes would pass military quality-control requirements after the tubes were machined.

- The lead design engineer has also claimed that he determined the maximum value for eccentricity of the raw aluminum tubes as needing to be between 0.05 mm and 0.1 mm.

With the reported exception of latitude given to the Director General of Tho Al-Fiqar to further tighten tolerances, few changes reportedly were made to the imported tube requirements specified by the 2000 Committee. According to an official from the Iraqi rocket program, no one was permitted to loosen the specification set by the 2000 Committee. However, the lead production engineer reportedly had the authority to further tighten specifications in order to ensure that usable parts were received from vendors. Otherwise the parts received might not meet the requirements stated in the pertinent procurement documents.

- The latitude reportedly available to the lead production engineer could explain why Iraq tightened the eccentricity specification on the tubes in early 2002—an action viewed at the time to be unnecessary for a rocket program. Tight eccentricity specifications reportedly were needed to pass military quality-control inspection—a check that could not be overruled by production personnel, according to reporting.

- Reporting indicates the hardness requirement for the nozzle was one of the few changes made after the committee completed its work, adding there were no other changes to the metal part specifications, including the rocket motor tube.

Table 4 Rocket Tube Dimensions				
	Iraqi	Technical for year	Drawing	
Rocket Chamber/ Tube Characteristic	1989	1993	1997	Specification After 2000 Committee
Outer Diameter	81.0 mm	81.0 +/- 0.2 mm	81.0 +/- 0.2 mm	81.0 + 0 / - 0.1 mm
Inner Diameter	74.4 mm	74.4 + 0.1 – 0.3mm	74.4 + 0.1 – 0.3mm	74.4 + 0.1 / - 0 mm
Final Length	868 mm	868 + 0.2/-0 mm	868 +/- 0.2/-0 mm	868 +/- 0.3 mm
Mass	1812g	1820 +/- 100g	1820 +/- 150g	1828 +/- 30g

A summary of Iraqi tube linear dimension specifications as found on 81-mm rocket drawings before and after they were reportedly tightened by the 2000 Committee.

Indigenous Tube Manufacture—A Possible Sign Baghdad Did Not Need High-Specification Tubes

Frustrated by its inability to import tubes, Iraq began indigenous production efforts in mid-2002 that ultimately raise questions about whether high-specification tubes really were needed for rockets. Dr. Huwaysh reportedly formed a committee in May or June of 2002 to study how to indigenously produce tubes for 81-mm rockets. One report indicates the committee—led by the heads of the al Nida and Tho Al-Fiqar State Companies—considered using the extruder at the Ur Establishment in Nasiriyah and two flow-forming machines at Tho Al-Fiqar to produce tubes. This committee conducted its work while foreign procurement attempts continued as well as indigenous manufacture of rockets using corroded tubes.

- Efforts to extrude tubes reportedly failed after four to six weeks despite assistance from the Badr and al Shahid State Companies and the University of Technology in Baghdad—including Dr. Sami Ibrahim. Multiple reports indicate the Ur extrusion press was too weak to handle high-strength 7075 T6 alloy. An effort by Badr to develop a special tool for the press reportedly ended with the war.

- Accounts differ on those responsible for developing the flow-forming techniques that successfully produced about 50 tubes per day through continuous operations at Tho Al-Fiqar. One piece of information credits the University of Technology and the 2002 Committee for developing the necessary heat treatment procedures while another indicates that the Director General of the al Nida State Company devised the production process. MIC reportedly envisioned the Sabah Nisan (Seventh of April) Company would make forgings for future operations, but this plan also was interrupted by the war.

The indigenous effort to produce tubes in the last months before the war resulted in production and handling standards that fell short of those required for the imported tubes. Reporting indicates that the lead production engineer gave Dr. Huwaysh some sample flow-formed tubes in late September or October 2002, noting that the production process was costly and time consuming. The lead production engineer also indicated that the best possible tolerance achievable on the outer diameter of flow-formed tubes was 81 + 0.2 / -0.1 mm—a figure that falls short of the requirements set for imported tubes. Another source indicates these aluminum tubes reportedly were flow-formed to a diameter of about 82.5 mm then machined to their final dimensions. To accommodate for the limitations in flow-forming technology, a separate, looser set of technical specifications reportedly were produced for indigenously produced rocket bodies (see Table 5).

- Reporting also indicates indigenously produced tubes were also handled differently than those that would have been imported. Between flow-forming steps indigenously manufactured tubes reportedly were shipped in ordinary wooden boxes or simply stacked for storage—a sharp contrast to the packaging and anodization requirements demanded by the 2000 Committee for imported tubes. The same reporting also indicates the tubes also reportedly were not individually wrapped or separated from each other and were sometimes positioned horizontally—again contrary to the 2000 Committee recommendations.

In late 2002, the lead production engineer informed Dr. Huwaysh that the indigenously produced flow-formed tubes could be used without affecting rocket performance—a significant shift from the 2000 Committee findings and one that the MIC director reportedly accepted. The lead production engineer reportedly passed this view to Dr. Huwaysh in a meeting attended by lead engineer Kubaysi, another member of the 2000 Committee.

- Reporting also indicates indigenously manufactured flow-formed tubes were successfully used in flight tests completed at the end of 2002 with the Iraqi Army approving the looser specification design in January 2003.

Iraq's Interest in Steel Rocket Body Tubes

About a year before Iraq reportedly began its effort to indigenously produce aluminum tubes, the head of Tho Al-Fiqar reportedly explored the option of making 81-mm steel bodies for rockets instead. *Baqi claims that he approved a proposal from the lead production engineer to study steel for the 81-mm rocket body as Iraq was struggling to import aluminum tubes. The lead production engineer reportedly delivered his proposal after a few months, but Baqi rejected it as it would have required almost a complete redesign of the rocket. Baqi claims he did not raise the issue with the lead production engineer again and that no 81-mm steel rockets were produced.*

- *Separate information confirms that Baqi rejected the notion of steel tubes for an 81-mm rocket on the basis that the modification was too significant for Dr. Huwaysh to accept. This reporting claims, however, that Baqi asked the lead production engineer to restart his work around 2002 because of the difficulties in acquiring aluminum tubes. The lead production engineer reportedly was insulted by Baqi's previous rejection, and refused to do the work.*

- *This reporting indicates that, around 2002, the lead production engineer produced some flow-formed steel tubes for use in 81-mm rocket bodies. The lead production engineer reportedly found the steel bodies weighed too much and the effort halted.*

Table 5
Tube Specification Comparison

Rocket Chamber/ Tube Characteristic	Specification Required After 2000	Indigenously Produced Tube 2003	Tubes Imported From Germany in Late 1980s	Original Italian Rocket
Outer Diameter	81.0 + 0 / - 0.1 mm	81.0 + 0.2 / - 0.1 mm	81.0 +/- 0.2 mm	81.0 + 0.4 / - 0 mm
Outer Diameter at 30.5 mm from ends		81.8 + 0.3 / -0.1 mm		
Inner Diameter	74.4 + 0.1 / - 0 mm	74.4 + 0.2 / - 0 mm	74.4 + 0.1 / - 0.3 mm	74.4 + 0.5 /- 0 mm
Final Length	868 +/- 0.3 mm	869 +/- 0.3 mm	868 +2 mm	868 + 0 /- 1 mm

A summary of Iraqi tube linear dimension specifications showing tighter specifications required after 2000 compared to those accepted for use from indigenous production in 2003. A second outer diameter specification for the indigenously produced flow-formed tube covers a 30.5-mm length on either end of the tube where the Iraqis allowed the tube diameter to significantly increase. Information on the imported German tubes—taken from an Iraqi quality-control document captured by ISG—provides figures inconsistent with Iraqi claims that it measured these tubes in 2003 and found them to be tighter than the 2000 Committee specifications. For comparison, the specifications of the Italian rocket that the Iraqis reverse-engineered is included.

Despite relaxed standards for indigenously produced tubes and increased international attention on the prospect of a renewed nuclear program, Baghdad continued to pursue high-specification aluminum tubes from abroad. According to reporting, in late 2002 or early 2003, the lead production engineer provided a representative of the Syrian-based Awad Amora Company with the same high-specification requirements for tubes as had been used with other prospective suppliers. Separate reporting confirms the Awad Amora procurement attempt, noting that Sa'ad Ahmed Mahmoud, the NMD representative at the Al-Rashid State Company, was told by MIC in 2003 to contact the company.

- Sa'ad also reportedly told the director of the NMD, General Husam Muhammad Amin about the ongoing procurement attempt. Amin reportedly became nervous about this continued effort to acquire goods subject to the nuclear controls under Annex 3 of UN Resolution 1051 and raised his concerns with Dr. Huwaysh. Nonetheless, the Awada Amora deal was still being negotiated at the time the war started, according to the reporting—a point ISG can independently confirm through captured documents.

- Dr. Huwaysh is the lone dissenter again in describing the events surrounding the dealings with Awad Amora, claiming the open bid was probably issued in 2002, not 2003.

Systemic problems such as bureaucratic inefficiencies and fear of senior officials seem to have played a significant role in the history of the 81-mm rocket and probably influenced why Iraq persisted in its effort to seek tubes with high specifications. Reporting suggests Dr. Huwaysh exhibited a rigid managerial style. For example, on hearing that the lead production engineer had succeeded in producing 50 tubes a day by continuously operating the two flow formers at Tho Al-Fiqar, Huwaysh reportedly insisted the production be doubled. The stress of working on the flow-forming project ordered by Dr. Huwaysh reportedly caused the Tho Al-Fiqar Director General to have a heart attack. Dr. Huwaysh also insisted on final approval of any changes to the rocket design after the 2000 Committee issued its results. Reportedly, the staff of Al-Fiqar feared Dr. Huwaysh's anger if modifications caused rocket failures.

- Fear of senior officials also traces back to the origins of the 81-mm rocket program in 1984 when Army officials reportedly were loath to challenge the decision by Husayn Kamil, then Saddam's son-in-law and head of MIC, to reverse-engineer and produce the weapon. Reporting indicates the Iraqi Army actually wanted 81-mm rockets for helicopters because they preferred the existing 122-mm and 107-mm rockets for ground-to-ground use.

- Reporting also reveals how the results of the 2000 Committee may have been influenced by a need to avoid problems with Dr. Huwaysh. One report claims the committee focused on specification and material problems to gain time to solve production problems at manufacturing facilities. Another report indicated Dr. Huwaysh wanted results quickly from the 2000 Committee; therefore, they did not attempt in-depth, detailed engineering analyses of rocket scatter. Instead, this report noted that the committee tightened some design specifications based only on the notion that doing so would improve rocket performance—a questionable engineering practice.

- Another report from the rocket program notes that many of the changes made by the 2000 Committee did not make technical sense, as members were simply tightening specifications in order to appear effective in addressing problems. The lead design engineer also told debriefers that rocket assembly was plagued by a lack of personal integrity, as people were more concerned with avoiding punishment or achieving quotas. The lead design engineer also claimed engineers and scientists would often make false claims or inflate their results in order to garner favor with Dr. Huwaysh.

- Fear of being held responsible for the cost of rejected tubes, components, or rockets also reportedly affected the lead production engineer and his decision to tighten tube specifications for the rocket program. A reportedly such punitive accountability practices were common for engineers or managers in Iraq when projects failed. With the high number of procured tubes involved, the cost to reimburse MIC would be excessive, probably leading to individuals being imprisoned until the debt could be repaid.

- Timing also could have affected why Iraq continued to use the tight specification requirements when dealing with Awad Amora. The acceptance testing by the Iraqi Army occurred around the same time that the Awad Amora deal was being broached—probably too soon for the new technical drawings from the flow-forming work to be forwarded to prospective foreign suppliers.

Iraqi Interest in 84-mm Tubes

ISG has been unable to corroborate reporting that suggested Baghdad sought 84-mm-diameter tubes—a diameter that would be too large for the 81-mm rocket launcher and a possible sign that Iraq intended some other nonrocket use for high-strength aluminum tubes. Information from a foreign government service received in mid-2004 indicates that the potential supplier was asked about supplying 84-mm diameter tubes—a change that would have resulted in a 3-mm increase in outer diameter as compared to the 81-mm size consistent with earlier purchase attempts. We have investigated this report further, and the connection with Iraq is unclear, as is the intended use of the 84-mm tubes.

A captured document reveals that Iraq already had 500 tons of 120-mm-diameter 7075 aluminum shafts at the Huteen State Establishment—stock that ISG believes Iraq could have used to produce tubes even larger than 84 mm if it intended to renew its centrifuge program. Reporting indicates Iraq imported 120 mm and 150-mm-diameter 7075 aluminum shafts before sanctions were imposed in 1990. Iraq had been using the material in the months before the 2003 war to support the Tho Al Fiqar flow-forming operations related to the 81-mm rocket program.

Carbon Fiber

ISG investigations have revealed that MIC's carbon fiber project was ultimately aimed toward the production of components for missiles; specifically, the combustion chambers of the al Fat'h missile. ISG has found no evidence to suggest that the MIC's carbon fiber project in 2001/2002 was connected to a program to restart uranium enrichment gas centrifuge production; however, the project would have allowed Iraq to acquire valuable carbon-fiber-related knowledge that could be used in the future reconstitution of a centrifuge program.

Carbon Fiber and Iraq's Pre-1991 Gas Centrifuge Program

Iraq's magnetic-bearing centrifuge uranium enrichment program began in mid-1988 when German engineers brought European centrifuge design information to Baghdad. Further deliveries by additional German engineers gave the Engineering Design Center (EDC) a significant body of centrifuge design details. These German contacts also arranged procurement and technology transfer applicable to the design, production and operation of centrifuge cascades.

- In 1989, maraging steel cylinder fabrication proved difficult, and the EDC acquired a consignment of about 20 carbon fiber cylinders from a German supplier in 1990. Iraq used some of these cylinders to develop test machines for its centrifuge program.

- Iraq was arranging for a shipment of winding equipment and materials when sanctions were imposed in 1990. A winder and large quantity of carbon fiber for EDC never reached Iraq.

After adopting UNSCR Resolution 687 in April 1991, Iraq ceased work on centrifuge development, although the Iraqi Concealment Committee took the decision to hide documents and equipment related to this program Although IAEA inspections were able to expose significant activities related to the centrifuge

program, Iraq continued to conceal significant centrifuge documents and materials until the defection of Husayn Kamil in 1995. This defection triggered additional disclosures to IAEA inspectors.

- Mahdi Shakur Al 'Ubaydi—the former head of the pre-1991 centrifuge program—continued to hide centrifuge components and documentation for future effort after the Husayn Kamil defection. We cannot link Al 'Ubaydi's efforts to hide these materials after 1994 to any instruction from Regime officials.

The EDC successfully produced two centrifuges using imported carbon fiber rotors and foreign assistance by mid-1990, one of which was tested with UF_6 feed. In 1989, the EDC began seeking machinery and raw materials to establish an indigenous carbon fiber production capability in support of a centrifuge production effort.

- This included the attempted procurement of a filament winding machine from the ALWO company in Switzerland and carbon fiber, which was sought through an order placed with the German company ROSCH (see Figures 9, 10, and 11).

However, ISG analysis suggest that, at the time of Desert Storm, Iraq did not have the capability to indigenously produce carbon fiber suitable for use in gas centrifuges.

- A former senior MIC executive revealed to ISG that, although Iraq had the capability to produce epoxy resin for carbon fiber applications, it had no capability to produce carbon fiber. The That Al-Suwari Company E-Glass plant could produce only low-strength fiber glass.

- An ISG site survey of South Taji, conducted in January 2004, found no evidence of carbon fiber production or a latent capability to produce carbon fiber.

Iraqi Concealment of Carbon Fiber-Related Activity, Materials, and Documents After Desert Storm

In the short period between the end of Desert Storm and Iraq's acceptance of Resolution 687, the EDC continued its development of gas centrifuges and resumed work on a 50-machine cascade—an effort that was part of a crash program to produce enriched uranium for a weapon by further enriching uranium from its safeguarded research reactor fuel. A senior nuclear scientist told ISG that, as soon as the 1991 Gulf war ended, a Presidential Scientific Advisor ordered the resumption of work on a 50-machine test cascade.

On adoption of Resolution 687, work ceased on the test cascade, and the Iraqi Concealment Committee took the decision to hide documents and equipment regarding gas centrifuge research from the UN. ISG analysis suggests that this was motivated by a desire to restart gas centrifuge research and production at a time when sanctions were lifted. However, by late-1991 the IAEA was actively removing and destroying the majority of Iraq's centrifuge research program.

- A senior Iraqi nuclear scientist recalled that one of the committee's first decisions was to hide both the EDC's Rashdiyah and Al Furat facilities and strip all nuclear-related material from them. The SSO was responsible for the removal and packaging of EDC documents and equipment.

- The scientist also revealed that Iraq intended to build a 100-machine cascade when sanctions were lifted and that the EDC documents and components collected by the SSO in 1991 were to be used in this effort (see Figure 11).

In a separate action, Husayn Kamil ordered the retention of at least one copy of all nuclear-related documents and some centrifuge components by a senior nuclear scientist. In 1995, following Husayn Kamil's defection, the IAEA seized a number of WMD-related documents and items of equipment from the Haidar Chicken Farm. The equipment seized included spools of high tensile, carbon fiber, and other centrifuge-associated components.

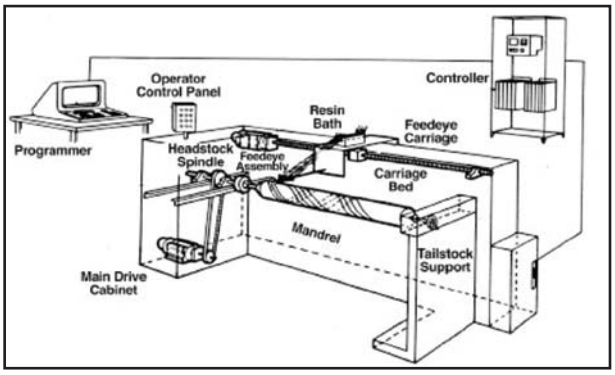

Figure 9. *Horizontal filament winding machine.*

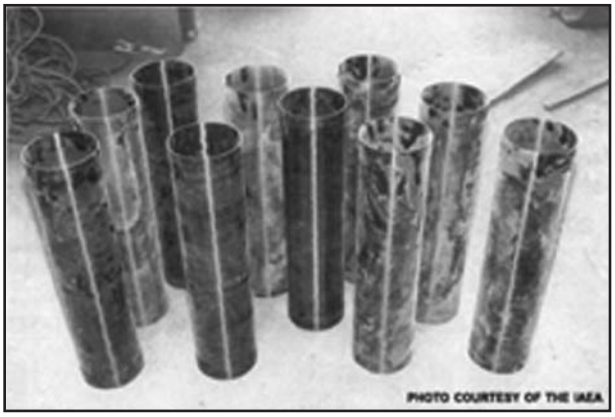

Figure 10. *Carbon fiber tubes.*

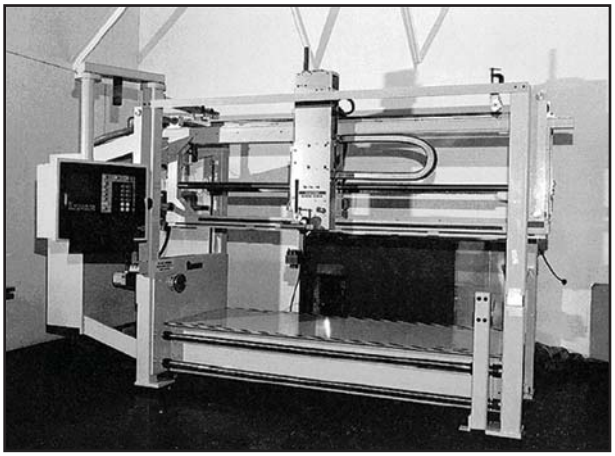

Figure 11. *Example of horizontal filament winding machine.*

In 2003, Al 'Ubaydi publicly revealed that he had retained centrifuge-related equipment and documents at his home throughout the 1990s and during many UN inspections. Al 'Ubaydi stated that this had been done in response to Husayn Kamil's order to keep a copy of all centrifuge-related documents**.**

The MIC Carbon Fiber Project in 2001/2002

The MIC carbon fiber project in 2001/2002 began exploring carbon fiber technology for use in the Iraqi Missile Program and was managed by the MIC-owned Al Rashid State Company. The material researched was specifically for use in the al Fat'h missile, and possibly the Al Naqwa anti-tank guided missile (ATGM). The project aimed to create an indigenous carbon-fiber-based production capability, based on previous experience with the Brazilian ASTROS Rocket in the 1980s, and included the refurbishment of one filament winding machine already within Iraq and the production of a second. At the time of Operation Iraqi Freedom, the refurbishment of the first machine was 50 percent complete, and the production of the second had not started.

Al 'Ubaydi, the former head of the Iraqi centrifuge project, played a role in the MIC carbon fiber project. ISG has not found any evidence to suggest that Al 'Ubaydi was involved in the project at the technical level. His main role was to head the committee that selected the company to build the filament winding machine.

In mid-2002, the Al Rashid State Company took delivery of a filament winding machine from the IAEC. This machine was to be refurbished because it was in a nonoperational state, and the design then copied for the second filament winding machine. According to a former MIC scientist the IAEC, the carbon fiber filament winding machine had not been used since 1990. The scientist was not aware of why the IAEC had such a machine.

ISG investigations and debriefs with multiple officials reveal that the minimum production diameter of the filament winding machines under development by MIC was 500 mm. This is consistent with the al Fat'h missile. This is significantly wider than

the carbon fiber rotor used in the pre-1991 Iraqi gas centrifuge, which had a diameter of approximately 145 mm.

Limited information indicates that the filament winding machines may have been used in the manufacture of components for the Al Naqwa ATGM. This missile has a diameter of between 150-200 mm and is much more closely matched to that of the pre-1991 carbon fiber rotor. However, ISG has been unable to find information to corroborate this claim, and a second report stated that the Al Naqwa ATGM motor case was made on a turning machine and not a winding machine.

With the exception of the filament winding machine that the Al Rashid State Company received from the IAEC, ISG has not found any further evidence of cooperation between MIC and the IAEC on the carbon fiber project, or any instances of the IAEC taking an interest in the progress or results of the research undertaken by MIC. Multiple source debriefs support this in that numerous former IAEC and MIC employees attest to the fact that the IAEC and MIC rarely worked together on joint projects.

Flow-Forming Machinery

ISG did not find evidence that flow-forming equipment was used to produce rotors for a reconstituted nuclear centrifuge program. As a result of IAEA inspections and Iraqi mishandling of equipment—in an effort to avoid potential military strikes—Iraq effectively lost its capability to conduct flow-forming operations of the type needed to support a centrifuge program.

- On 23 June 2003, an ISG team inspected the Umm Al Marik site. It was severely looted and vandalized. The team saw several of the machine mounts where the flow formers had been mounted prior to the war. The remains of one large flow former remained, stripped of all usable parts.

Beginning in 1989, Iraq was pursuing advanced flow-forming technologies and equipment from foreign sources. One company that provided considerable technical support and machinery to the Iraqi industrial base was the H&H Metalform Company of Germany. Iraq's Engineering Design Center failed to develop a maraging steel centrifuge rotor due to manufacturing limitations, which helped precipitate the shift to trying to acquire a carbon fiber production capability.

- As of 1991, H&H Metalform had sold nine flow-forming machines to Iraq.

- In February 1993, a UN Inspection Team visited the Nassr Plant; they inventoried and recorded the serial numbers of eight Flowtronics, H&H flow-forming machines. Iraqi officials contend that these machines were used to produce 122-mm rockets and components (see Figures 12 and 13).

Figure 12. *H&H flow formers.*

Figure 13. *Dispersed and destroyed flow-forming machines (Tho Al Fiqar).*

Planned Magnet Production Lines at Al Tahadi

ISG has not uncovered information indicating that the magnet production capability being pursued by Iraq beginning in 2000 was intended to support a gas centrifuge uranium enrichment program, but the magnet production lines would have allowed the Iraqis to preserve their skills for a centrifuge magnet program.

- Iraq investigated use of centrifuges as one approach to manufacturing enriched uranium in their pre-1991 nuclear program. One of the centrifuge designs investigated included use of magnetic bearings to support the rotor. The pre-1991 Iraqi nuclear program was able to successfully test a magnetically supported rotor.

- Iraq purchased Aluminum-Nickel-Cobalt (AlNiCo) and Cobalt-Samarium (CoSm) ring magnets for their pre-1991, magnetic-bearing centrifuge program. Centrifuges can be designed to use a variety of ring magnets of different dimensions and materials.

ISG also cannot refute Iraq's claim that the magnet production lines it sought beginning in 2000 were intended for other than routine industrial and military uses. The declared use of the magnet production lines were for production of ring magnets in the Saham Saddam Missile and for field telephones. According to Iraqi officials, the Iraqis chose to purchase the production lines *in lieu* of buying the magnets, which would have been cheaper. In addition, the Iraqis wanted the experience and knowledge that would eventually come with operating the lines. The Al Tahadi site was heavily looted after Operation Iraqi Freedom, and no documents or equipment remained at the site.

Procurement Details

The Al Tahadi Company contracted to purchase magnet production lines on two occasions beginning in 2000—neither of which were completed or delivered. Iraqi specifications for the magnet production lines were typically vague. The Al-Sirat Company, a trading company responding to MIC requests, initiated the first of two procurement efforts in 2000. The procured line would include cast or powered magnets of all types, including Aluminum-Nickel-Cobalt (AlNiCo) and Samarium Cobalt (SmCo)—the latter was used in Iraq's pre-1991 nuclear program. According to a MIC engineer experienced in magnet production, this contract for magnet production lines was signed in 2000 with a Romanian company.

- The contract included equipment to manufacture AlNiCo ring, cubicle and cylindrical magnets ranging in mass from 0.5 to 500 grams—a range that could have supported production of magnets needed for centrifuges. Such magnets, however, also would have had to conform to specific density and morphology requirements for use in centrifuges.

The second contract for magnet production lines was signed in 2001 with a Belarusian company. Only some of the equipment specified in the contract was received, including a press machine and a mixer. The contract had included equipment to produce permanent ferrite magnets.

Rotating Machinery Department

ISG has not been able to find evidence to show that the machine tools ordered in 2002 by a new department in MIC's Saad Company called the Rotating Machinery Department were intended for a renewed centrifuge program, and available information suggests that the equipment was not capable of supporting such work. The equipment sought included machines for rotary balancing and spin testing, as well as a milling machine and a lathe.

- Such machines can be used to balance equipment such as turbines, pumps, and compressors. They are also applicable to developing skills useful for centrifuge design and testing. Iraq's pre-1991 nuclear program used rotary balancing machines, a technology used widely in industrial applications, in development of centrifuges for enrichment of uranium.

- The Ibn Younis Center, part of the MIC's Saad Company, formed the new Rotating Machine Department in mid-2002. The department was small—only four engineers—when it was set up. The intention was to establish a profit center to perform repair and maintenance work on the many compressors, turbines, and other rotating machines in Iraqi industry.

In mid-2002, Dr. Khalid Ibrahim Sa'id, a former PC-3 scientist, asked about the capability of the balancing machine ordered for the newly formed Rotating Machinery Department. ISG has received conflicting information as to whether the inquiry shows interest in its potential use for a centrifuge program or was an attempt to ensure that the equipment did not violate provisions of UN Security Council Resolution 1051, Annex 3 of the Ongoing Monitoring and Verification Plan.

- Dr. Sa'id, a high-ranking Baathist and Secretary of the Industrial Committee at the time, asked the Director General of Ibn Younis Center whether the equipment being sought would violate the provisions of Annex 3. The Director General asked engineers in the Rotating Machinery Department whether the equipment could be used for centrifuges. The response from the engineers was "no" because the equipment did not meet the specifications required for centrifuge use.

- The Ibn Younis director, however, reported that Sa'id's involvement stemmed from his role as the secretary of the Industrial Committee, which gave him responsibility for allocations of foreign currency for procurements. MIC Deputy Director Dagher sought non-MIC currency allocations for the Department of Rotating Machinery purchases, and Sa'id reportedly selected un-used IAEC funds for these purchases. Huwaysh told ISG that it would make no sense for the IAEC to have used its budget to buy equipment for the MIC.

- Al 'Ubaydi stated in an interview that he was sufficiently curious about Sa'id's interest to press a friend, a former engineer in the pre-1991 centrifuge enrichment program and member of the Rotating Machinery Department, for information on potential inquiries he may have received concerning the reconstitution of a centrifuge program.

The purchase by the Rotating Machinery Department machinery used purchasing channels that were not the norm—adding to the suspicion surrounding the order. The MIC, of which the Rotating Machinery Department was part, had its own purchasing procedures. The order for the machines was placed using IAEC resources for the purchase—a procedure that would be outside the normal MIC purchasing procedures. ISG has not discovered the reason for the alternate purchasing arrangement.

- Huwaysh told ISG that it would make no sense for the IAEC to have used its budget to buy equipment for the MIC.

The Rotating Machinery Department also sought a balancing machine, which, at the minimum, would have helped Iraq maintain important skills that could have been applied to a renewed centrifuge program. It is not clear whether this machine could balance centrifuge rotors, given that the machine specifications called for balancing much heaver components, up to 500 kgs. The balancing machine that was ordered by the Ibn Younis Center for the Rotating Machinery Department was never received.

Balancing machines were purchased by at least two other organizations in the MIC—which Iraq declared to the IAEA as not being covered by Annex 3 (see Table 6).

- The Specialized Institute for Engineering Industries (SIEI) purchased a vertical-type balancing machine with a maximum balancing speed of 1,200 rpm. This is an engineering support company that provides resources for the engineering and industrial sector.

- The Factory for the Repair of Jet Engines (FRJE) purchased a vertical-type balancing machine with a maximum balancing speed of 4,000 rpm. The mission of FRJE is to repair various types of jet engines used in the Iraqi Air Force (see Figure 14).

Table 6
Comparison of Rotating Machinery Department-Ordered Balancing Machine With UN Sanctions Detailed in the UN Nuclear Controls Known as Annex 3

Specification	Balancing Machine Ordered	Annex 3 Restrictions
Rotor Length[a]	1500 mm	> 400 mm
Swing/Journal Diameter[a],[b]	10-120 mm	>75 mm
Mass Capability[a]	750 kg	0.9 to 23 kg
Balancing Speed[a]	3000 rpm	>5,000 rpm
Residual Imbalance[b]	0.0015 kg/mm/kg	Better than 0.010 kg/mm/kg
Drive Type[b]	Drive and belt options supplied	Belt

[a] Centrifugal balancing machines designed for balancing flexible rotors (Annex 3, item 57.1)—all conditions must be met to be prohibited.
[b] Centrifugal balancing machines designed for balancing hollow cylindrical rotor components (Annex 3, item 57.2)—all conditions must be met to be prohibited.

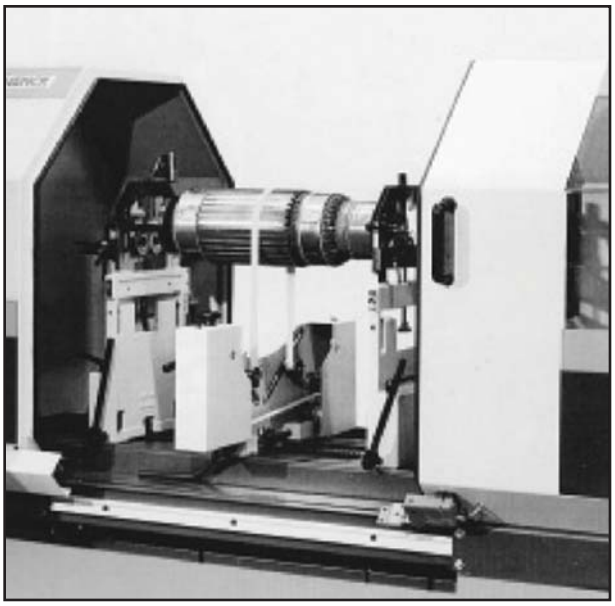

Figure 14. *Typical horizontal balance machine.*

Investigation of Potential Centrifuge-Related Facilities

ISG investigations of sites related to the pre-1991 centrifuge program did not uncover any attempt to utilize these facilities to support a renewed centrifuge effort. ISG site visits revealed significant looting and destruction, which have rendered the sites inoperable.

- Site exploration of the Al-Furat site conducted in September 2003 revealed looting and occupation by squatters. In the pre-1991 program, a centrifuge assembly hall and cascade had been planned for Al-Furat. The IAEA removed the centrifuge-related equipment from this site in the 1990s.

Support Facilities

ISG investigation into known or potential support facilities also found no evidence these sites had been involved in any renewed enrichment work. Along with research and development and production facilities, a centrifuge program would require a large infrastructure for fabrication, assembly, testing, and material support. The following sites were investigated because of their potential as locations where key elements of the reconstitution could take place:

- Ash Shaykhili Storage Facility

- Al Karama State Company
  (Al-Waziriya Site (al Samud Factory, Khadimiyah Site (Ibn Al-Haytham), Al-Fatah Factory (Al Quds Factory)

- Basdr and Umm Al-Marik State Companies
  (Khan Azad Military Production Plant)

- Al-Tahadi State Company

- Salah al-Din State Company
  (Samarra Electronics Plant)

- Al-Nida State Company

- Nassr State Company
  (Taji Steel Fabrication Plant)

- Ur State Company
  (An-Nasiriyah Aluminum Fabrication Plant)

Ash Shaykhili Storage Facility
Ash Shaykhili Storage Facility—prior to Operation Iraqi Freedom—had stocks of fluorine, Anhydrous Hydrogen Fluoride (AHF), and UF_6 cylinders in Building 27A. Building 27B also contained a specialized ventilation system with scrubbers, which would be ideal for pilot-scale development of UF_6 production process. In the early 1990s, the IAEA either destroyed or collected centrifuge components from various sites across Iraq and placed them in storage at Ash Shaykhili. The IAEA inspectors, upon returning to Iraq in late 2002, performed a detailed inspection of the Ash Shaykhili storage site and made several more inspections of the site in early 2003.

In late April 2003, the site was surveyed by Coalition forces, which found it damaged and burned from bombing and looting. Also in early July 2003, an ISG team returned to Ash Shaykhili to assess the condition of Buildings 27A and 27B. They found that the contents of Building 27A had been burned and everything inside Building 27B had been removed, except for portions of the air-handling duct work (see Figure 15).

The results of environmental samples taken at Building 27B, during the April 2003 ISG site visit, indicated the presence of fluorides at the site, which we suspect are the result of pre-1991 activities. ISG did not find that any nuclear-related activity had been established here and based on the current condition of the Ash Shaykhili, ISG concludes that it would not be able to support any centrifuge activities without major rework.

Al Karama State Company
The al Karama State Company consists of several facilities that have precision machining capabilities. Al Karama's subordinate facilities are:

- Waziriyah Site (al Karama Missile and Electronics Plant).
- Khadimiyah Site (Ibn Al-Haytham Missile Production and RDT&E Center).
- Al Samud Factory (Abu Ghurayb Missile and GSE Support Facility).
- Al Fatah Factory.
- Al Quds Factory.

Although the facilities associated with the Al Karama State Company continued to function during the 1990s, ISG did not find that any of these sites were used to support a uranium enrichment program.

Al-Wazeriya Site
An ISG exploitation team visited the Karama Al-Wazeriya Site in early August 2003 and concluded that the site appeared to have been abandoned for at least several months. According to one source at this site, no missiles were produced at the facility after the site was bombed during Operation Desert Fox in 1998. Iraq did not rebuild the missile production capability at Al-Wzaeriya after Desert Fox, and instead used the site as the headquarters for Al Karama.

Khadimiyah Site (Ibn Al-Haytham Missile R&D Center)
The Khadimiyah Site was part of the al Karama State Company and Iraq's primary production and integration facility for the al Samud and al Samud II Short-Range Ballistic Missile (SRBM). The facility suffered damage from Coalition air strikes in late March 2003.

Al Samud Factory (Abu Ghurayb Missile Facility)
Al Samud Factory was Iraq's primary al Samud component production facility. The al Samud Factory was significantly damaged during Operation Iraqi Freedom by Coalition air strikes in late March 2003. ISG visited the site on 28 September 2003 and verified both the bomb damage and the effects of the massive looting.

Badr and Umm Al-Marik State Companies (Khan Azad Military Production Plant)
Badr fabricated mechanical components for the pre-1991 gas centrifuge program and initially retained flow-forming capability after Operation Desert Storm. Such flow-forming machines—had they been maintained through the years—could have been used for making metal rotors. ISG has not found that these machines were used for fabrication of rotors for gas centrifuges in a renewed centrifuge program. Site visits conducted in May 2003 revealed that the site was in severe disarray (see Figure 16) and could not function again without extensive renovations.

Al-Tahadi State Company
Al-Tahadi was established in 1995 by the MIC. Former PC-3 engineers from Tarmiyah were transferred to this facility where they continued their work on electromagnetic devices and transformers and their research on permanent magnets. Al-Tahadi had a good lab for measurement of magnetic properties that included a computerized system that could measure the magnetic properties of hard and soft materials. Al-Tahadi was looted, and no documents or equipment remain at the site.

Salah Al Din State Company (Samarra Electronics Plant)
The Salah al-Din Company is an electronics company located near Samarra that produced radar equipment, antennae for various purposes, communication equipment, printed circuit boards for electronic equipment, and plastic covers for agricultural purposes. Exploitation of this site in July 2003 confirmed that the plant appeared to produce different types of electronics and electronic components for various uses. The presence of certain industrial chemicals seems to be consistent with the types of industry found at the facility. The facility itself appeared to be in reasonably good shape. This site did not suffer from some of the large-scale looting and scavenging prevalent in other facilities.

Al-Nida State Company
This facility, along with the Rashid State Company's Tho Al-Fiqar Factory, had general-purpose machine shops utilizing CNC lathes, CNC milling centers, hydraulic presses, welding equipment, coordinate measuring machines, quality-control laboratories, nondestructive testing equipment, and CAD/CAM computers prior to the recent war. Such facilities would be necessary for a reconstituted centrifuge program. An ISG team visited the Al-Nida site in late August 2003 and found that the entire plant had been systematically looted of all equipment, computers, and documents.

Rashid State Company's Tho Al-Fiqar Factory (formerly the Nassr State Establishment Mechanical Plant)
Prior to Operation Desert Storm, the machining plant at Nassr produced centrifuge and EMIS components for Iraq's nuclear weapons program. After Operation Desert Storm, an IAEA inspection team found vertical flow-forming machines. In August 2003, an ISG exploitation team visited this site. The team found four flow formers, none of which were functional because they lacked parts.

- Also found were seven, five-axis machine tools. The Iraqis assisting the team mentioned that the five-axis machine tools could not function as designed. The team also found two-axis milling machines, four Hartford milling machines (two vertical and two horizontal), and large stamping and press machines for serial production of tail fins for rockets.

The team also found thousands of 81-mm aluminum tubes. The Iraqis stated that on the site approximately 90,000 tubes were classified as rejected tubes or tubes that did not pass prescribed testing. The Iraqis stated that they had a 10-percent acceptance rate of domestically made 81-mm tubes. Figure 17 shows a nonfunctioning flow former at Tho Al-Fiqar, aluminum tubes for 81-mm rockets, and a fully assembled 81-mm rocket.

Ur State Company (An-Nasiriyah Aluminum Fabrication Plant)
Iraq attempted to indigenously produce aluminum tubes for its 81-mm rocket program by using the extrusion facilities at Ur State Company. The extrusion equipment reportedly was designed to extrude only 6063 type aluminum alloy; thus, attempts made to extrude 7075 aluminum alloy (the type required for centrifuges) were unsuccessful.

Figure 15. *Damage at Ash Shaykhili Building 27B and remaining air ducting in July 2003.*

Figure 16. *Destruction at Badr and Umm Al Marik State Companies (Khan Azad Military Production Plant), May 2003.*

Figure 17. *Flow-former (left); aluminum tubes (center); 81-mm rocket (right) found at Rashid State Company'sTho Al Fiqar factory.*

Uranium Enrichment—EMIS

ISG judges that the Iraqi Regime did not attempt to reconstitute the EMIS program after 1991, although many of the former EMIS engineers and scientists still worked for either the IAEC or MIC in roles that could preserve their technical skills. These technical skills, if maintained, would have helped build the foundation for a future nuclear weapons program and would have allowed scientists to reenter a nuclear program further up the learning curve. Since Operation Iraqi Freedom, significant looting and damage have occurred at most of the dual-use manufacturing facilities that supported the pre-1991 EMIS program. There are no indications that the Iraqi Regime attempted to preserve the EMIS technology either through former EMIS scientists and researchers or by retaining technical documents and historical files on the former EMIS program, although one scientist associated with this pre-1991 program appears to have unilaterally kept relevant records and some parts that would have been useful to restarting such an effort.

Electromagnetic Isotope Separation (EMIS)

The electromagnetic isotope separation process (EMIS) was the primary technology used by the Iraqis for uranium enrichment in their pre-1991 nuclear program. This process was chosen because of the availability of this technology in open literature and the technical capabilities of the Iraqis. In EMIS, a source containing solid uranium tetrachloride (UCl_4) is electrically heated to produce U^+ ions. The ions are accelerated by an electrical potential to high speed. These charged particles follow a circular trajectory in a magnetic field as shown in Figure 18. The diameter of the circle depends upon the strength of the magnetic field, the velocity of the ion, and the mass of the ion. The ions accumulate after passing through slit apertures at the collector.

An EMIS system includes the following processes:

- Isotope separation—electromagnetic equipment used to separate the uranium isotopes (see Figure 19).
- Chemical recovery—chemical processes used to remove uranium from separator collectors (see Figure 20 for type of collector used in Iraqi program).
- Uranium conversion—used to convert the uranium removed from the separator collectors to a form that is usable either in further enrichment equipment or other downstream processes.

A flow diagram of the pre-1991 Iraqi EMIS process, shown in Figure 21, demonstrates the various steps. Iraq conducted its research and development into the EMIS process at the Tuwaitha Nuclear Research Center and was outfitting a production-scale uranium enrichment facility at Tarmiya, a duplicate site under development at Ash Sharqat, and a feed material production plant near Mosul called Al-Jazira.

A schematic of the Iraqi EMIS separators setup is shown in Figure 22.

Facilities

The pre-1991 EMIS project consisted of three primary production sites. These sites included the Al Safa'a EMIS Plant uranium enrichment facility at Tarmiya (isotope separation and uranium recovery), the Al Fajr EMIS Plant uranium enrichment facility at Ash Sharqat (isotope separation and uranium recovery), and the Al-Jazira feed material production plant near Mosul. Ash-Sharqat was being built as a backup facility to Tarmiya. Also, several sites were utilized for fabrication of equipment needed for EMIS, including the Zaafaraniya Mechanical Workshop, the Zaafaraniya Power Supply Production Facility, and Al-Radwan (Batra Military Production Feed Plant).

Al Safa'a EMIS Plant at Tarmiya

The Al Safa'a EMIS Plant uranium enrichment facility at Tarmiya was designed to produce enriched uranium for the Iraqi nuclear weapons program, using the EMIS process. It was externally complete by January 1991 but was not fully operational. The plant had two types of EMIS buildings: alpha units (R120s) for primary uranium enrichment and beta units (R60s) for enriching material produced by the alpha units to weapons-grade.

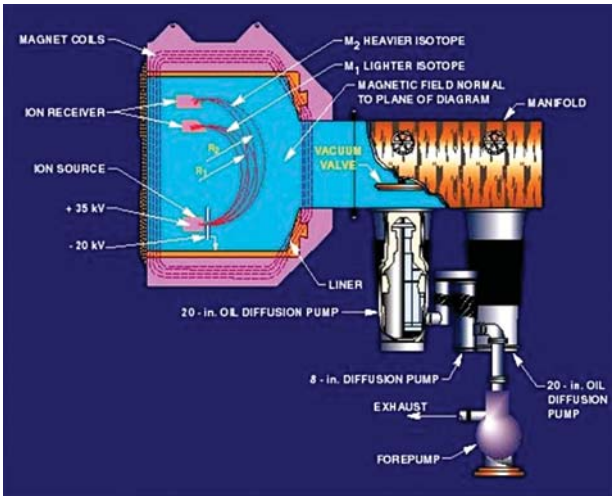

Figure 18. *Example of EMIS separator and vacuum system.*

Figure 19. *Photograph of Iraqi EMIS electromagnet.*

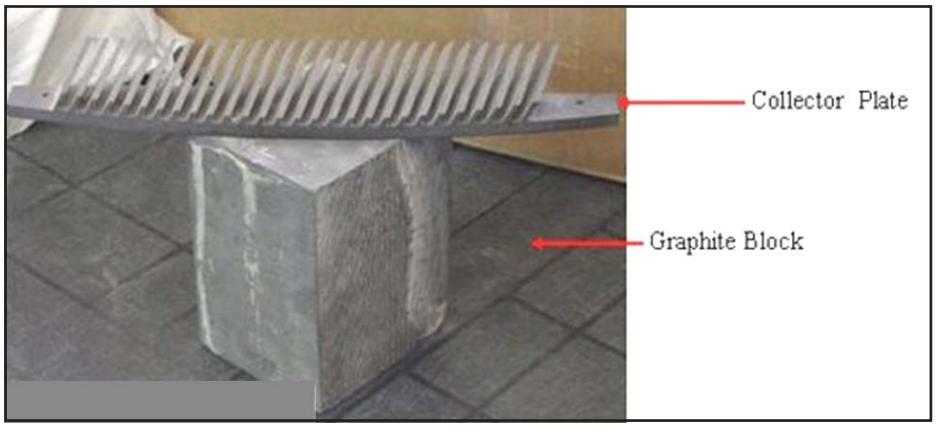

Figure 20. *Collector plate removed from Iraqi scientist's home, July 2003.*

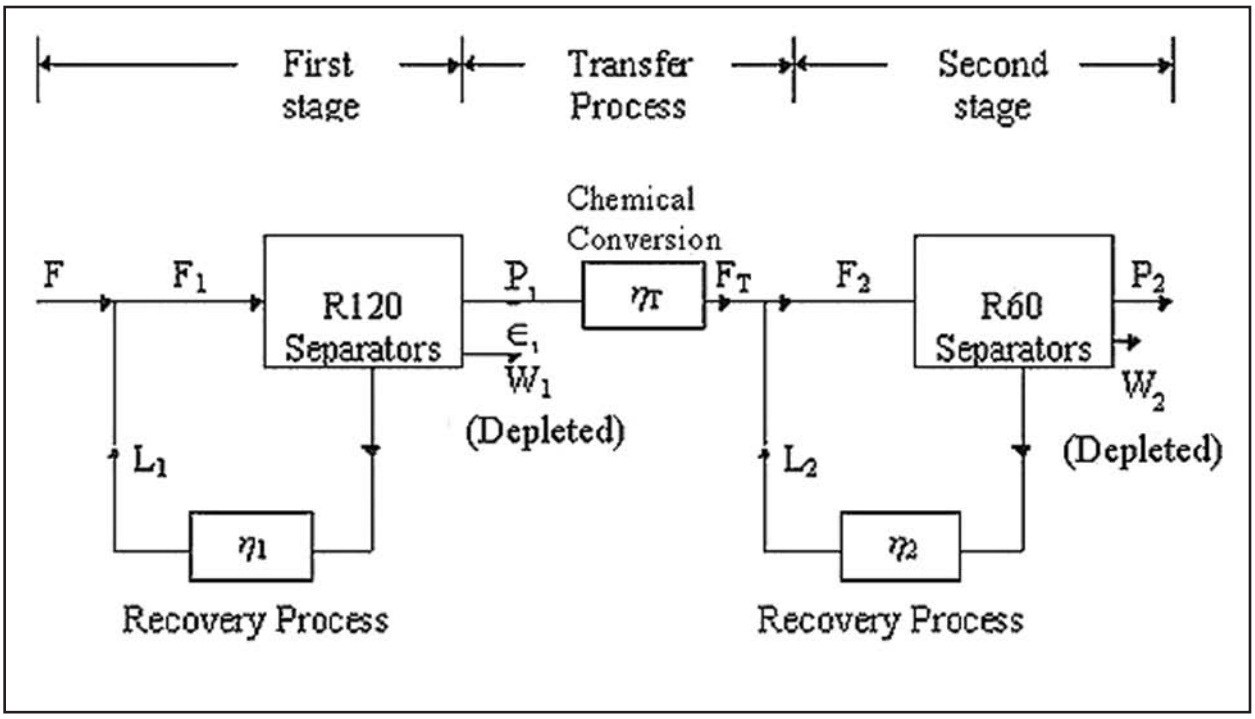

Figure 21. *Flow diagram of the Iraqi EMIS process.*

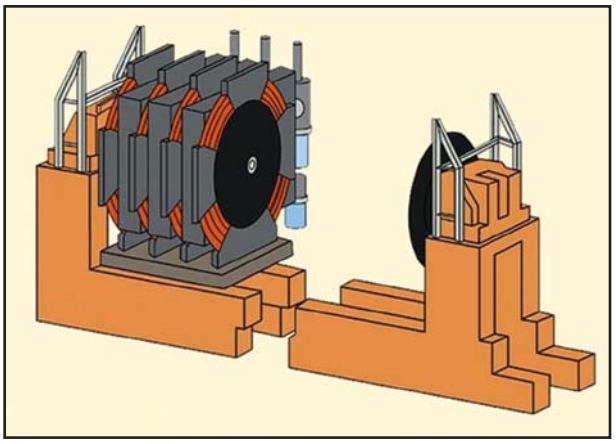

Figure 22. *Schematic of the Iraqi EMIS machines.*

In 1991, the Al Safa'a EMIS Plant uranium enrichment facility at Tarmiya was in the process of bringing online R-120 separation units, with eight units completed and functioning. An Iraqi mechanical engineer, working at the site, estimated that 70 to 80 percent of the equipment in the building was destroyed by the 1991 Gulf war. IAEA inspectors also supervised the destruction of EMIS equipment beginning in mid-1991.

The EMIS facilities occupied most of the central portion of the Tarmiya site. The shell of the large alpha-enrichment building is located near the northern entrance of the facility (see Figure 23). The damaged shell of the smaller beta enrichment building is in the south-central portion of the facility.

Most of the major buildings at Tarmiya were extensively damaged by coalition air strikes during Desert Storm. In late 1992, it was rendered inoperable under the UN-mandated destruction. Since 1991, the plant engaged ostensibly in chemical pilot plant construction, design, and low-volume production of a number of specialty chemicals for Iraq's weapons programs (see Figure 24).

In late October 2003, a senior Iraqi researcher at Ibn Sina stated to an ISG team that, from 1993 to 1994, he had created a small processing line consisting of 15 mixer-settlers in which he produced "very pure" phosphoric acid. After 1995, he claimed to have designed a second phosphoric acid purification line using packed columns instead of mixer/settlers (see Figure 25). According to the researcher, the purification line was dismantled in 1997, and the equipment (the mixer-settlers) was placed in storage (see Figure 26). The researcher claimed that any extracted uranium was treated as an impurity and disposed of as part of the waste generated by the processes.

There were no indications of any renewed uranium enrichment operations at Tarmiya. ISG did learn, however, of a phosphoric acid purification study conducted in the mid-1990s at the site that recovered what Iraqi staff described as an "insignificant" amount of uranium that was diluted and discharged downstream as waste.

Al Fajr EMIS Plant at Ash Sharqat

The Al Fajr EMIS Plant uranium enrichment facility at Ash Sharqat was constructed to be a replica of the Tarmiya site. The Iraqi's decided late in 1987 to execute this project to serve two purposes: 1) to replace Tarmiya if the latter is rendered completely nonoperative for whatever reason, or 2) to serve as a backup to enhance production when required. The Al Fajr EMIS Plant main production buildings were destroyed during Desert Storm and in accordance with UN Security Council Resolution 687 in 1991. According to Iraq's declarations, initial installation of EMIS separators at Ash Sharqat was to begin only after Tarmiya separators had been installed. The site has not been rebuilt as of March 2003.

Al-Jazira (Mosul Feed Materials Production Facility)

Al-Jazira (a.k.a. Mosul Feed Materials Production Facility) was established to produce nuclear feed materials for the EMIS program, namely UO_2 and UCl_4. The facility was built in the 1980s and put into operation in 1989.

In 1992, the MIC took control of this facility, and it was subordinated to the General Establishment for Extraction Operations. The primary purpose for this facility was to extract raw iron from the iron-rich ores around the area of Mosul. We know from IAEA inspections that the facility had also been converted since 1991 to make pigments for paint. In October 1996, control of the plant was transferred from the State Establishment for Extraction and Mining Operations (SEEMO) to Al-Kindi State Establishment in Mosul. In 1997, the name of this facility was changed to the Center for Extraction. The purpose of the facility continued to be the extraction of iron oxide from scrap metal. Additionally, the facility engaged in the research for the production of hydrochloric acid. In 2003, this facility was renamed the Al-Ramia Factory.

As of late April 2003, the facility included buildings associated with administration, electricity generation, ammonia production, hydrochloric acid production, waste storage, and chemical laboratories. Extensive looting had occurred throughout the buildings and some structural components (such as piping) had been ripped out. Although portions of this site remained active, ISG has not uncovered any evidence that this site has been used for any fissile material processing since 1991.

Al-Zawra State Company

The Zaafaraniyah Power Supply Production Facility (also known in 1991 as Al-Dijjla and renamed Zawra Electronics Plant in 1992) was designed to produce electronic components for the Iraqi uranium enrichment program using the EMIS method. The factory became operational by June 1988. The facility was capable of manufacturing electronic switch gear and high-voltage power supplies for EMIS.

The Zawra facility was inspected by ISG in August 2003. It had been severely damaged by vandals and looters. Several industrial machines were found on site and there was a warehouse for parts. Most of the warehouses and machine shops were empty at the plant. The Zawra site does employ civilian workers and is trying to become productive again.

Al-Nida State Company (Zaafaraniya Mechanical Workshop Al-Rabiyah)

The Al-Nida State Company (Zaafaraniyah Mechanical Workshop Al-Rabiyah), also known in 1991 as Zaafaraniyah Nuclear Fabrication Facility Al-Rabiyah, produced vacuum chambers and components

Figure 23. *Destroyed Alpha-Enrichment building at Tarmiya (photo taken by ISG Team, December 2003).*

Figure 24. *Building at Tarmiya where phosphoric acid purification occured at Ibn Sina in the 1990s (photo taken by ISG Team, December 2003).*

for Iraq's EMIS program. The facility was capable of manufacturing major metal components for the EMIS process. The status of the facility as of March 2003 is shown in Figure 27.

An ISG team visited the Al-Nida State Company site in late August, 2003 and found that the entire plant had been systematically looted of all equipment, computers, and documents.

Al-Radwan (Batra Military Production Facility)
The Al-Radwan (Batra Military Production Facility) produced components for Iraq's EMIS program. This facility was not damaged during Operation Iraqi Freedom; however, since early summer of 2003, the installation was subjected to massive looting, which destroyed or damaged the critical elements needed to restart production operations. At least 60 percent of the fabrication and production buildings had their roof material stripped and their internal components removed. The remaining buildings were lightly to moderately damaged during the looting.

Al-Nassr Al-Adhim State Company
Al-Nassr Al-Adhim State Company, known prior to 1997 as the State Enterprise for Heavy Engineering Equipment (SEHEE) and also known as Daura, is a large heavy equipment fabrication and metallurgical facility that was used to produce vacuum chambers for the pre-1991 600-mm and 1,200-mm separators. This facility was not damaged during Operation Iraqi Freedom. ISG exploitation teams visited the site in January 2004 and observed process equipment (tanks, piping, industrial materials, and chemicals) stored at the site but did not uncover any evidence of activities associated with a uranium enrichment program.

Disposition of EMIS-Related Equipment

Equipment and components from Iraq's pre-1991 EMIS enrichment program remained in Iraq after 1991. ISG has not discovered any effort by the Iraqi Regime to use these items to reconstitute an EMIS enrichment program. The pre-1991 EMIS project required several types of components and equipment, such as power supplies, ion sources, control systems, magnet field coils, magnets, magnet poles, return iron, ovens (for vaporizing the UCl_4), vacuum systems (pumps, liners, vacuum chambers, piping), and material collector assemblies. In the early 1990s, IAEA inspectors collected and either destroyed or had the equipment transferred from the various EMIS facilities (i.e., Tuwaitha, Tarmiya, Ash Sharqat, Al-Jazira) to Ash Shaykhili and Al-Nafad (open area adjacent to Ash Shaykili) for storage. In early 2000, the Iraqis transferred some of the EMIS components (ring-shaped coils; no disks) stored at Ash Shaykhili to the Al Shaheed State Company, a brass and copper products company. Most likely, this transfer was accomplished to salvage copper from the EMIS coils for other industrial needs. ISG found an Iraqi video that showed scrap material identified as copper and coils at Al-Shaheed State Company in April 2002 being collected and disposed of in a smelter.

Figure 25. *Packed columns used in phosphoric acid purification studies conducted at Ibn Sina in the mid-1990s (photo taken by ISG Team, December, 2003).*

Figure 26. *Mixer-settlers in storage at Ibn Sina (photo taken by ISG Team, December 2003).*

Figure 27. *Facility, Al-Nida State Company (Zaafaraniyah mechanical workshop) in March 2003 prior to start of OIF.*

Figure 28. *Items stored at former EMIS scientist's home—high-purity tantalum sheets (left), technical papers (center), and mass spectrometer (right).*

Laser Research in Iraq

The Iraqi government at the time of Operation Iraqi Freedom was supporting laser research and development work in military and industrial applications. ISG found no evidence of a renewed laser isotope separation (LIS) program to enrich uranium.

- ISG believes that only a few Iraqi scientists have the knowledge and experience to recommence an LIS project. Furthermore, the technology and infrastructure to support an LIS program does not appear to exist in Iraq.

Laser Related Work After Desert Storm

After Operation Desert Storm, laser work that had been under way in the IAEC as part of an effort to enrich uranium in the 1980s was transferred to universities and to the MIC. The various laser projects conducted at these organizations allowed the Iraqis to retain much of their technical know-how in laser technology.

- In 1992, Dr. Falah Hamza—the former head of pre-1991 research efforts to enrich uranium with lasers—asked Husayn Kamil to provide additional funding for the IAEC Laser group. Hamza claimed high-power lasers could be used for air defense as well as for enrichment, seeming to imply that there were other, valuable uses of lasers and laser technology in the Iraqi military and industrial complex. Husayn Kamil agreed to the additional funding, perhaps to learn if Hamza could further develop laser technology into a usable uranium enrichment method.

- In 1993, an IAEC Optical Center was established at the University of Baghdad. Hamza's laser project was transferred to the Optical Center, and Hamza became one of the Center's Group Leaders.

- In 1994, laser projects in Iraq were organizationally moved from the IAEC to the MIC and in 1997 were physically consolidated at the Laser Research Center. It was later named the Al-Razi State Company and became known as the Ibn Khaldun Laser Center. Al-Razi was co-located at the Alwiyah Drug Industrial Center Ibn Al Baytar.

- According to the MIC Director Dr. Huwaysh, Al-Razi engaged the Technology University to assist in laser projects. The Dean of the Physics Department received a 6-million-dinar contract, which was the largest contract MIC had with a university professor. This occurred sometime after laser research was started at Al-Razi in 1997.

- The former Minister of Education, Dr. Humam 'Abd Al-Khaliq Abd Al-Ghafur, stated that the Dean of the Plasma and Laser Institute at Baghdad University, up until Operation Iraqi Freedom, was Dr. Nafi 'Abd Al-Latif Tilfah and that the Baghdad University of Technology also conducted laser research. In October 2003, he stated that he was not aware of any nuclear-related research being conducted at these institutes.

- According an interview with Dr. Nafi 'Abd Al-Latif Tilfah, Dean of Baghdad University's Institute for Laser and Plasma Studies in November, 2003, post-1991 laser research was conducted at several locations including the Baghdad University Institute for Laser and Plasma Studies, the Baghdad University of Technology, Mustansiriyah University, and at the Al-Razi Company. Tilfah stated, however, that he was not aware of any LIS-related laser work being conducted at these institutions.

A knowledgeable source indicated that some of the important team members of the 1980s LIS team were working on the development of a copper vapor laser (CVL) in 1997 at Al-Razi—a technology with potential applications to LIS. This work continued until mid-2002 with the successful development of a CVL designed to pump a dye laser. The CVL development effort was led by an Iraqi scientist, who successfully operated a CVL in March or April 2001. The scientist hosted a demonstration of the 10-watt CVL to MIC Director Huwaysh on 5 July 2002. The CVL system reportedly was placed into storage in 2002 in an adjacent underground facility. In April or May of 2003, the underground facility adjacent to the main Al-Razi facility was visited and found to have been looted, and equipment was missing. The Iraqi scientist stated that after the CVL demonstration he worked on a barium vapor laser up until Operation Iraqi Freedom.

- The Iraqi scientist said LIS work was never done at Al-Razi. He also stated that Huwaysh expressly forbade such work and, therefore, no one would have attempted LIS. The Iraqi scientist also indicated he would have been aware of any such work at other facilities because he was the only laser researcher in Iraq with a functioning CVL.

- The Iraqi scientist indicated no written reports were produced on the Al-Razi CVL work. Exploitation of documents from Al-Razi contains very few mentions of LIS or uranium isotope information, and no mention of the CVL development work has been found in these documents.

In the 1990s Iraq pursued various laser application. However, LIS and its nuclear application does not appear to have been part of this work.

- According to one scientist, who started working at Al-Razi in 2002, laser work for military applications such as jamming, range finding, communications and guidance was being conducted at Al-Razi. Also, according to the same scientist, one group at Al-Razi was working on a carbon dioxide (CO_2) laser for an antimissile defense project. This project reportedly was abandoned because of technical problems.

- Laser work also was being done with Nd-YAG and Nd-Glass lasers at Al-Razi. Additionally, an investigation using hydrogen fluoride and deuterium fluoride lasers for an antimissile defense program was being studied.

Current Status and Future Potential

A few former LIS scientists remain in Iraq, but the equipment and facilities needed to reconstitute an LIS program are extremely limited. For example:

- Following Operation Iraqi Freedom, the CVL that had been demonstrated to the MIC Director in mid-2001 was reportedly stolen from the underground facility in which it was placed. ISG was unable to determine the location or the current status of the CVL.

- Although Al-Razi was not damaged during Operation Iraqi Freedom, it was heavily looted afterward.

Iraq's Pre-1991 LIS Efforts

Beginning in 1981, Iraq committed significant resources to exploring the use of LIS techniques for enriching uranium. This work was prompted by then Vice President of the Iraqi Atomic Energy Commission, Dr. Humam 'Abd Al-Khaliq 'Abd Al-Ghafur. LIS techniques that were under development included atomic vapor laser isotope separation (AVLIS) and molecular laser isotope separation (MLIS).

These pre-1991 LIS efforts were under the auspices of the IAEC, rather than the PC-3. The LIS program was terminated in 1988.

- The results of the 26th IAEA On-Site Inspection in Iraq led to the conclusion that the level of skills, equipment, and infrastructures available in Iraq was totally inadequate in the pursuit of any meaningful activity in LIS.

- A report written by Dr. Faleh Hassan Hamza has revealed the results of the former Iraqi AVLIS effort were inconclusive—his team could not confirm that uranium was actually separated. The MLIS experiments successfully enriched sulfur but could not achieve repeatable results with uranium. Based on these experiments, Dr. Hamza wrote a review of the state-of-knowledge of LIS, concluding that Iraq had neither the technology infrastructure nor the capability to purchase the necessary equipment to achieve success with LIS. The laser work stopped in 1988.

Rail Gun Summary

Iraq's efforts to develop rail guns appear to have been for air defense, but ISG found that laboratories established to partly support an IAEC project led by Dr. Khalid Ibrahim Sa'id—the head of Iraq's pre-1991 nuclear weapons design and development program—also could build skills needed for a renewed nuclear weapons effort.

- ISG has not uncovered information that shows that Iraq's work on rail guns in the late 1990s was part of a renewed nuclear weapons effort—although some of the reporting acknowledges this potential.

- Rail gun equipment and materials uncovered by ISG similarly do not appear to have been part of a nuclear weapons design and development effort, even though a few items—with further development—had the potential of supporting such work.

- Theoretically, the rail gun could provide the range and altitude capability to shoot down aircraft in the no-fly zone, a reported goal of Saddam's (see inset).

Rail Gun Efforts

Multiple sources and captured documents indicate that, in early 1999, Sa'id initiated a project under the IAEC to develop a rail gun, an experimental device that, if further developed, could, in theory, have applications including nuclear weapons research and antiaircraft weapons. The IAEC rail gun project—named Al Muharek al Khati or "The Linear Engine"—occupied two primary locations, a laboratory at the Roland Missile Facility near the Rashid Air Base and a small facility within former residential compound outside the Tuwaitha Nuclear Research Center. The Roland site was destroyed by Coalition bombing in March 2003, while the facility outside of Tuwaitha—called the "Technical Research Branch"—was the subject of an ISG site visit in August, 2003.

- We know from postwar debriefings that Sa'id used the Technical Research Branch as headquarters of the IAEC rail gun project. Documents found at the site and former scientists involved in the work indicate that Dr. Karim Kalif Mohamid was the head of the photography unit of the Technical Research Branch.

Numerous Iraqi scientists interviewed by ISG stated that the IAEC rail gun was an effort to develop an antiaircraft weapon—a point that we believe is supported by documents captured at the Technical Research Branch and at IAEC's headquarters at Tuwaitha. A set of papers found at the site—which we have determined were written by Sa'id—connect the rail gun to antiaircraft work for the Ministry of Defense. Former scientists involved in the effort indicate at least two progress reports were submitted to the Air Defense Commander, Lieutenant General Shaheen. These same sources, as well as documentary information found by ISG, indicate Shaheen visited the IAEC rail gun project (see inset on Saddam's Interest in Antiaircraft Weapons).

- Other indications the rail gun project was intended for antiaircraft applications include the need for a technical cadre specialized in air defense, a plan to locate the work at the air defense site at the al Rashid Military Camp, and the intent to use a visual device to target the projectile—according to notations in Sa'id's papers. The document also notes plans in early September 1999 to test the rail gun on what appears to be salvaged military aircraft from an airplane repair company.

- An Iraqi scientist told ISG that the IAEC rail gun project was one of many projects at the Tuwaitha Nuclear Research Center that were supported by the Ministry of Defense. The same source indicates any scientist could suggest an air defense project—purportedly a means to obtain extra funding and recognition.

Despite indications that the IAEC rail gun was intended for antiaircraft use, the project preserved skills that could support a renewed nuclear weapons design effort. Given his past leadership in the nuclear weapons program, ISG believes that Sa'id clearly

Saddam's Interest in Antiaircraft Weapons

The antiaircraft application is consistent with Saddam's reported intense interest in air defense technologies*. One scientist told ISG that Saddam became obsessed with achieving a capability to shoot down an enemy aircraft in the no-fly zone and had challenged the scientific community to rally around that goal. Saddam reportedly believed that achieving such a capability would render the no-fly zone ineffective and foster a change in political climate that would hasten the lifting of sanctions.*

- *Fadil al-Janabi, head of the IAEC since 1996, indicates that Saddam would often attend monthly meetings with his son Qusay to discuss air defense projects—meetings Janabi also claims to have last attended in February 2003.*

Fadil al-Janabi indicates that Saddam tasked him to develop knowledge in atomic energy areas and support air defense projects. Air defense was the IAEC's number-one priority.

understood that his rail gun project also dealt with technical subject areas applicable to nuclear weapons research. In one section of text that we suspect was part of his proposal to build the IAEC rail gun, Sa'id refers to work on gas guns—technically simpler devices that also can accelerate projectiles to high speeds.

- Sa'id's notes describe that gas gun work had been planned for al Atheer—a site where he and his staff had planned to design, develop, and assemble nuclear weapons as part of the pre-1991 weapons program. Iraq planned to use gas guns as a research tool for its pre-1991 nuclear weapons program.

According to a scientist involved with the rail gun program, Sa'id also indicated one of the objectives of the project was to train a new generation of IAEC scientists in applied physics. One source indicated that working on the rail gun project was like attending a seminar where staff could learn new subjects such as plasma physics, electrical engineering, motion physics, high-speed photography, and flash radiography.

- Documentation found at the Technical Research Branch also describes work in each of these areas but noted in the context of an air defense project (see inset on Technical Research Branch).

- A proposal for a 10-year effort to recruit and train university students was also found at the Technical Research Branch site.

The IAEC Technical Research Branch

According to a document captured by ISG, the IAEC Technical Research Branch consisted of various laboratory units, which include:

- ***Photography Unit:*** *The aim of this unit was to strengthen the scientific tests on various physics phenomena for the purpose of treating the photographic montage and also to study the specifications of standard and digital cameras.*

- ***Pressure Measuring Unit:*** *Aimed at counting the pressure of various materials and their mechanical specifications.*

- ***X-ray Unit:*** *Aimed at studying matter specifications, counting the speed of moving bodies, and the natural behavior of movement of these bodies through x-ray photography.*

- ***Electronic Unit:*** *Aimed at testing and measuring electrical specifications (resistance, induction, voltage, and current) and also repair of electronic instruments and computers.*

- ***Programming:*** *This unit dealt with the physical problems and factors that affect scientific programming.*

One Iraqi scientist told ISG that Sa'id's rail gun pursuits were more personally motivated because he was nearing the end of his professional career and he wanted to increase his stature with Saddam. This source indicates Sa'id may have wanted to leave his mark with a high-profile project—like shooting down

a Coalition aircraft. Another Iraqi scientist noted that, even though Sa'id had been removed from the IAEC after reaching the compulsory retirement age in mid-2002, he continued to run the rail gun project and eventually Saddam reinstated him at the IAEC.

- Postwar document exploitation efforts reveal Sa'id applied–probably in late 2002—for a position as the Director General of the Industrial Committee. His application details work experience from 1989 to 2001, noting his work on the IAEC rail gun project as well as work on Iraq's "complete, final, and inclusive document for the canceled project/Group 4." ISG doubts that Sa'id would have needed to pursue the new job or need reinstatement if he had been part of a concerted Iraq effort to restart Baghdad's nuclear weapons program.

Sa'id managed, nonetheless, to initiate his IAEC project despite a more experienced rail gun effort having been reinitiated under the MIC at Al Tahadi in 2000. Reporting from former scientists in the rail gun program suggests that the IAEC project seems to have been the favored effort as the leaders of the MIC project reportedly were asked to join the IAEC rail gun program. At least one scientist from the Al Tahadi rail gun project reportedly also was tasked to assist the IAEC, participating in three meetings between late 2001 and June, 2002. The same source indicates the Al Tahadi effort also provided equipment to the IAEC rail gun (see inset on MIC's Rail Gun Projects and Figure 29).

Documentation found at the Technical Research Branch also indicates an agreement was being discussed to have Al Tahadi repair and examine the IAEC rail gun.

ISG has found only tenuous indicators that would suggest the rail gun was part of an effort to renew a nuclear weapons program. One Iraqi scientist recalled Sa'id's role in gas gun work for the pre-1991 nuclear weapons program and thought it possible that the rail gun would be applied to a similar research effort. Documents found by ISG also indicate the IAEC rail gun effort was associated with a number of scientists from the former nuclear weapons design and development program including other former members of Iraq's pre-1991 nuclear weapons program (see inset on Tapping PC-3 Expertise).

MIC Rail Gun Projects

Iraq's interest in rail guns for air defense, according to a senior official involved in the program, traces to around 1993, when an Iraqi scientist recently returned from his Ph.D. studies in Russia, wrote to the MIC to advocate the development of rail guns. *This letter reportedly generated research and development efforts at the High Voltage Establishment—an outgrowth of the electromagnetic isotope separation (EMIS) portion of the pre-1991 nuclear weapons program at Tarmiya. The High Voltage Establishment was renamed Al Tahadi in 1995. Rail gun efforts fell under the direction of Dr. Khaluq Rauf Hamdi, who arrived at the establishment in 1994.*

- *The MIC program at the High Voltage Establishment succeeded in producing a rail gun with a barrel 1 meter long, capable of shooting a 1-gram, quadrilateral-shaped polycarbonate projectile to a speed of 400 to 450 meters per second, according to an official involved in that program.*

- *ISG found other evidence that the rail gun at Al Tahadi had reached a speed of 1 km/sec in March 2000. The so-called Iraqi Electromagnetic Rail Gun used a capacity of 55 kJ to accelerate a 1.5-gm projectile to the 1-km/sec speed.*

Although well under the limits of Annex 3 (2,000 meters per second), the MIC rail gun project was routinely hidden from inspectors*. According to a former senior official involved with the work, before UN/IAEA inspectors would visit the site, Iraqi personnel took efforts to conceal equipment associated with the project. The project was killed in 1995 when MIC Official Amir Rashid Al 'Ubaydi became concerned that the research and development effort would be discovered.*

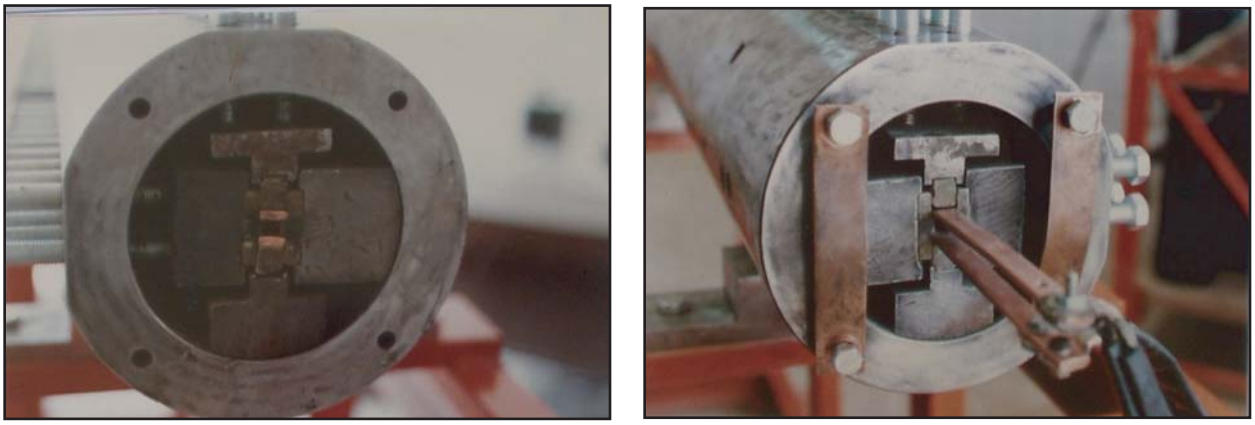

Figure 29. *Cross-sectional view of Al-Tahadi rail gun showing how the rails are held with insulators and metal supports in a photo obtained from Hahdi Hadi Jasim.*

- Based on information gathered through debriefings and documents, ISG has determined that the IAEC rail gun effort was a classified program, and at least part of it was code-named Project 505—actions reminiscent of how Iraq classified its pre-1991 nuclear weapons programs. A scientist associated with the rail gun project claims the rail gun project was classified not because of the sensitivity of its application or technology—which appears to have been drawn from open literature—but to create an aura of importance.

- Another source associated with the rail gun effort recalled an emergency meeting called by Sa'id in 1995—under the authority of Husayn Kamil, the former head of Iraq's WMD programs–to ask about the feasibility of manufacturing man-made diamonds. When told the project was impractical, Sa'id reportedly indicated this was why the rail gun project was needed. Some types of artificial diamond production technology utilize skills similar to those needed in developing nuclear weapons.

An ISG inspection of the Technical Research Branch facility in August 2003 found evidence of new dual-use laboratories and equipment. When further developed, these dual-use technologies could possibly have been used in a nuclear weapons development program, especially in the area of hydrodynamic testing. Other activities discovered at the laboratory were clearly devoted to the IAEC rail gun project.

Rather than using official IAEC channels, Sa'id privately contacted outside contractors to acquire several key pieces of equipment for the Technical Research Branch laboratory—a suspicious approach but one that we cannot link to a renewed nuclear weapons effort. To acquire a 300-kV flash X-ray machine, for example, Sa'id contracted with a trusted colleague, a former PC-3 Group 4 scientist who was working at the University of Technology in Baghdad. This colleague contracted with former coworkers at the Ibn Firnas Company for work done under contract to the university. The project reportedly was kept secret from the director of the Ibn Firnas Company as a means to provide Sa'id with financial cover.

- A colleague of Said also contracted with the Al Qaswar Company to provide a timing device using laser diodes to measure the speed of the rail gun projectile. The Al Qaswar Company is registered in the name of the wife of one of the Ibn Firnas employees that had worked on the flash X-ray system.

- One colleague of Sa'id—an expert in materials analysis—received a contract from Sa'id to outfit a laboratory for impact behavior studies. Part of this contract included a gun device to measure the impact of projectiles on various materials. This became the pressure measuring unit of the Technical Research Branch. Information from a senior official in the rail gun program indicates this unit was limited in its ability to gather material property data—the kind of data of interest in a renewed nuclear weapons effort—because of the lack of diagnostic equipment (see Figures 30 and 31).

Tapping PC-3 Expertise for the IAEC Rail Gun

Sa'id may have turned to former members of the pre-1991 nuclear weapons program, codenamed PC-3, for a variety of reasons—ranging from established competence, personal and professional relations, or even some hidden intent to tap this expertise to train a new cadre of nuclear scientists. *Debriefings of Iraqis associated with the rail gun project and captured documents reveal the following former PC-3 personnel were connected to the effort:*

- ***Dr. Khalluq Ra'uf Hamdi****—Former head of PC-3 Group 2B, responsible for Electromagnetic Isotope Separation (EMIS). Hamdi served as Sa'id's deputy on the rail gun project and the head of the IAEC Technical Research Branch.*

- ***Dr. Sabah al-Noor****—A trusted colleague of Sa'id and another former PC-3 Group 4 powder metallurgy specialist. Sabah reportedly contracted with Sa'id for the production of projectiles for the IAEC rail gun, a flash X-ray machine, and shock physics laboratory.*

- ***Dr. Abdullah Kandush****—Former head of PC-3 Group 4B (Applied Physics) and weaponization theoretician. Kandush had responsibilities for heat transfer issues.*

- ***Basil al-Qaisi****—Former Director at the Saad Center, al-Qaisi was associated with the funding of the rail gun project.*

- ***Dr. Faris Aziz al Samarra****—A former official in the pre-1991 centrifuge program–an effort administratively outside of PC-3 and the nuclear weapons design effort. Dr. Faris was the director general of Al-Shahid Company that produced copper and brass products. According to a captured document, he was to provide oxygen- free copper for the rail gun project.*

- ***Jamal Ja'far****—A former pre-1991 centrifuge design engineer who, according to a captured document, reviewed designs for the rail gun project in August, 1999. A senior scientist associated with the rail gun project indicates that Jamal Ja'far was one of two highly regarded engineers in Iraq who could be brought into a variety of projects for consultation.*

According to a former senior official involved with the effort, the IAEC antiaircraft project was focused on improving the efficiency of the rail gun and making it more transportable in the years before the war, rather than conducting materials experiments like those used in nuclear weapons research. Overall efficiency for converting electrical energy into projectile speed was poor, estimated at only one to three percent, according to a former senior official involved with the program.

- In an effort to reduce the size of the rail gun so it could be weaponized for use on the back of a vehicle-mounted 100-mm antiaircraft gun frame, the Iraqis considered the use of homopolar generators to replace the bulky capacitors—390 of them—that made up the research device. Iraq planned a steady progression of building homopolar generators in sizes from 0.15 mega joules, to 1.5 mega joules, to 15 mega joules, but none of these items reportedly were completed because of the lack of precision machinery.

- The same official indicates that materials work was limited at the Technical Research Branch and that, because of limitations in the availability of diagnostic equipment, these tests primarily consisted of studying the impacts caused by projectiles on steel plates. Crude approaches to the study of materials using piezoelectric materials were reported.

Sa'id's documents refer to the need to conduct experiments above the 2,000-meter-per-second limit posed by the Annex 3 nuclear controls, specifically calling for speeds as high as 10,000 meters per second. ISG believes that this velocity range was used for calculations to estimate the electrical equipment needed to power a laboratory research tool for exploring the relationships between projectile mass and barrel length as found in references made later in the document.

- The IAEC project reportedly used three different barrels—two square annulus barrels measuring 15 mm and 30 mm, as well as a circular barrel measuring 32.5 mm in diameter. According to a senior official involved in the project, Iraq attained its best results with the circular barrel, which was able to accelerate a 28 gram polycarbonate projectile to a speed of 885 meters per second (see Figure 32 summarizing the Iraqi Rail Gun progress).

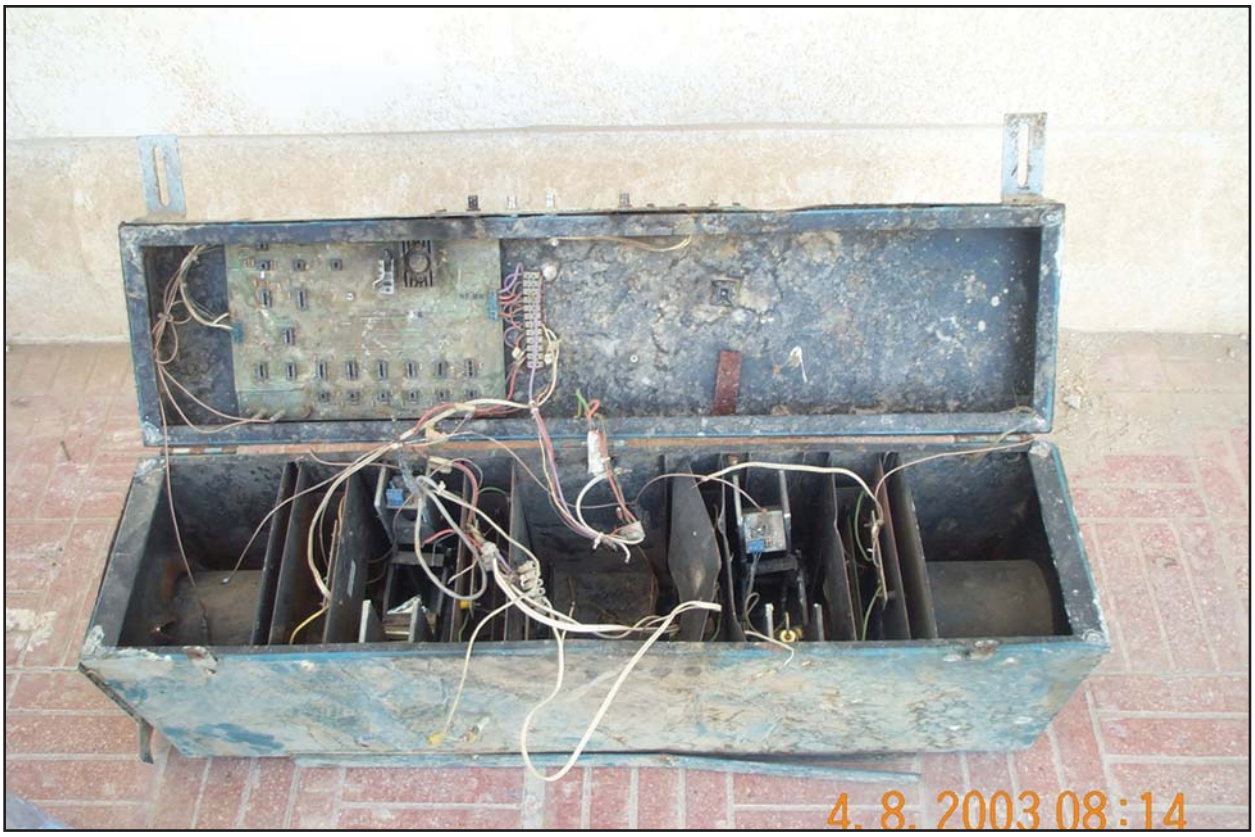

Figure 30. *Technical Research Branch facility inspection—velocity measuring device for rail gun projectiles.*

Figure 31. *Technical Research Branch facility inspection—shock impact materials test rig.*

Dr. Khalid Ibrahim Sa'id

Dr. Khalid Ibrahim Sa'id was a senior Ba'ath Party leader with ties to the Presidency. Prior to the first Gulf war, he had served as head of PC-3 Group 4, the nuclear weapon design and development group, and, after spending most of the 1990s as Director of Research in MIC, became Secretary to the Industrial Committee, which coordinated projects between the production ministries. Sa'id was reportedly killed running a Coalition roadblock on 8 April 2003.

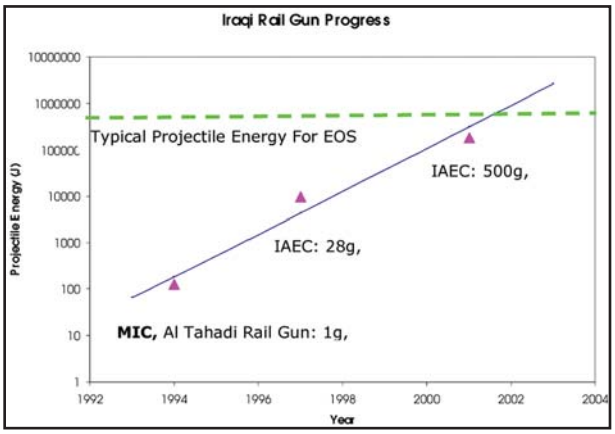

Figure 32. *Iraqi rail gun progress.*

Alternate View Of Science Projects and The Rail Gun

It should be noted that some senior scientists believed the Rail Gun project had neither scientific merit nor utility as an air defense weapon. *In September 2003, Dr. 'Amir Hammudi Hasan al-Sa'di, former Presidential Scientific Advisor, commented on science projects and the Rail Gun in particular. 'Amir said that the state of scientific research in Iraq had declined after the UN imposed sanctions on Iraq following the 1991 Gulf war—the new generation of scientists could not distinguish between validating an idea and being able to mass-produce and deliver systems. He further said that Saddam had decreed that any scientist with an idea could make that idea a present to the presidency. Special-interest groups—those who stood to benefit from the project—would then press for its adoption.*

If a knowledgeable person did not step in to put a halt to a scientifically invalid project, the project would proceed. *Specifically, 'Amir mentioned the rail gun and certain decoys as examples of poorly developed concepts crafted to win Saddam's support and garner funds. 'Amir lamented that such programs wasted resources and efforts. In an earlier interview 'Amir assessment was more direct; he stated that the rail gun was "obviously not" for use against aircraft and viewed the idea as ridiculous. 'Amir said he did not know what the purpose of the rail gun was but suggested that it was probably a worthless project that someone thought up just to get more funding.*

Issues Related to Nuclear Weapons Design and Development

ISG judges that Iraq has not worked on nuclear weapons design since 1991. ISG investigated Iraq's nuclear weapon design and component manufacture capabilities through interviews with scientists and other government employees, site visits of historically-associated Iraq nuclear weapon facilities, and exploitation of captured documents.

Casting Technology

ISG has not identified a materials research and fissile component manufacturing capability that would be required to reconstitute a nuclear weapons program. Working with molten highly enriched uranium requires special consideration for criticality during the melting and solidification process. ISG found no evidence that Iraq had acquired or developed the technology of dealing with casting and machining issues of highly enriched uranium.

- Iraq's pre-1991 nuclear programs experimented with crucibles and with vacuum induction furnaces, both imported and indigenously constructed, to varying degrees of success, to produce components in molds. Several types of crucibles and crucible materials were used in casting experiments with metallic uranium.

- An Iraqi scientist provided information to ISG that is consistent with other sources that Iraqi nuclear program work at Al Atheer was just getting started in January 1991 and that uranium metal casting work was accomplished within the limitations of the equipment at hand. Iraqi scientists encountered difficulties in use of vacuum casting furnaces to melt uranium metals prior to pouring into molds and with the molds. According to inspections, several small spherical and cylindrical pieces were produced, but of relatively poor quality as pertaining to void and impurity inclusions.

- According to Iraq's CAFCD addendum in 2002, a new Ceramics and Alloys Section had been formed under the IAEC Physics and Materials Directorate in 2000 to investigate ceramic coating of metals. ISG was unable to determine if the investigations were directed toward solving pre-1991 problems that Iraqis encountered in pouring of uranium metal into molds during the casting process.

- An ISG inspection team visited the South Taji industrial complex and searched for evidence of uranium metal production capabilities and nuclear-weapon-related component production. As a result of building damage, looting, and prior removal of equipment, ISG was not able to accurately assess the prewar functions of the facility.

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Explosive and Lens Fabrication Capabilities

ISG has not identified any explosive lens development effort in Iraq that was associated with a renewed nuclear weapons program. ISG has found, however, that the Al Quds Company—a new MIC establishment created in 2002—had a technical department, which built an explosive test facility capable of conducting research. Such a facility appears well suited for types of explosive research that could be applicable to conventional military and nuclear weapons research.

- According to a captured letter, the General Manager of the IAEC Technical Research Branch sent a three-person group to the new Al Quds Company to "conduct tests and checks" in December 2002.

Iraq has maintained explosive development activities supporting conventional military weapons systems. This could be considered a dual-use activity, and

although not as exacting in tolerance requirements, the technology could be reapplied to explosive lenses for nuclear applications.

- ISG has not resolved the issue of missing explosive lens mold drawings of concern to IAEA inspections in March, 2003. A letter from Maj. Gen. Eng. Hussam M. Amin, Director General, National Monitoring Directorate, from February 2003, and acquired by ISG, indicated continued concern with missing explosive lens mold drawings that supposedly contained critical information.

High-Speed Switches

ISG obtained evidence from recovered documents and from debriefings of Iraqi scientists that Iraq utilized high-speed switches—like those of potential interest for nuclear weapons development—in support of its rail gun projects. ISG has found no direct evidence that the interest in special high-speed switches after 1991 was in support of a nuclear weapons program.

- In July 2003, ISG obtained information that in 2002 a graduate student at the Mustanseriya University was working on an electrothermal accelerator using the rail gun under development at al Tahadi. This igniter could be considered a type of specialized, high-speed switch.

- Iraqi documentation recovered by coalition forces describes prototype testing of a gas switch with breakdown times that are likely less than one microsecond. The gas switch experiments proceeded within the rail-gun project. An ISG subject matter expert determined that the described switch was probably in violation of the Annex 3 guidelines of prohibited items.

ISG has found other indirect and fragmentary evidence of interest in specialized switches. However, ISG has not found this information to be connected to research into nuclear weapons.

- The Military Industrial Commission in 2000-2001 was interested in electromagnetic pulse generation that was described as a box containing a laser-controlled thyristor, a type of specialized switch.

- A CD-ROM recovered in 2003 from the Religious University in Baghdad contained files regarding spark-gap switches and electrothermal accelerators.

Fireset Development and Testing

ISG obtained limited corroboration of previously reported, pre-1991 fireset development status. No new information regarding fireset development was found. ISG found no evidence that Iraq continued fireset development or testing after 1991.

- An Iraqi scientist reported to ISG that development of one complete 32-point fireset directly applicable to nuclear weapon detonation initiation was completed prior to February 1990. A second fireset was being assembled and environmentally hardened in 1990 but was never completed. Work on both firesets was ceased in April 1991, and the firesets were evacuated to a safehouse and later returned to Al Atheer. One fireset was reported to be exhumed from rubble at Al Atheer in 1996 or 1997 and was turned over to inspectors. ISG confirmed that this information is consistent with that previously reported by Iraq. ISG has not been able to independently confirm the disposition of the second fireset reported to have been assembled in the pre-1991 nuclear program.

Neutron Generators

ISG was not able to find that Iraq had resumed any work related to neutron initiators/generators for a renewed weapons program. The only neutron generation capability found by ISG pertained to a previously known capability used for non-weapons-related research under way at the IAEC at Tuwaitha. This project is described in more detail in the IAEC Issues portion of this report.

Migration of the Capabilities From the PC-3 Nuclear Weapons Project

Starting around 1992, Iraq transferred many scientists from the defunct nuclear weapon program into several Iraqi scientific establishments. We have not found clear indications of the intent behind these personnel moves, but some of the work they pursued would have inherently preserved skills that could be applied to possible future nuclear weapon work.

PC-3 was officially dissolved in March 1992. Several senior Iraqi officials stated that there was an initial program to move PC-3 personnel into matching skill centers within the MIC to sustain skills. Some person-

PC-3 Comprised Four Main Groups

Group	Focus
1	*Gaseous Diffusion Enrichment and Centrifuge Enrichment* *(Group One is later detached to become the Engineering Design Center)*
2	*EMIS, Chemical Enrichment, Chemical Engineering (Feed Products)*
3	*Administrative Support, Models, Studies, and Databases*
4	*Weaponization (High-Explosive Lenses and Neutron Generator Development)*

Examples of Former PC-3 Scientists Migrating to New Positions by the Late 1990s

Person	Position	Late 1990s	Pre-1991 PC-3
Dr. Khalid Ibrahim Said		Secretary Industrial Committee	Former Head of Group 4
Dr. Ja'far Diya' Ja'far	Presidental Advisor	Industrial Committee	Former Head of PC-3
Dr. Mahdi Shaqr Al 'Ubaydi	Director General	Saad Center	Former Head of Group 1/EDC
Dr. Muhammad Habib		Razi State Company	Formerly of Group 4
Dr. Hikmat N'aim Al-Jalu	Director General	Ibn Sina	Formerly of Group 4
Dr. Faris Al-Samarra'i	Director General	Al Samud State Company	Former Engineer Group 1/EDC
Dr. Dhafir Al-Azzawi	Director General Al Raya	Zahfal-Kabir	Formerly of Group 4
Dr. 'Abdallah Kandush	IAEC	International Div Head	Formerly of Group 4
Dr. Fadil Al-Janabi	Director		IAEC
Dr. Abd Al-Rizaq Hammudi Al-Karaguli		Ibn Sina Center	Formerly of Group 2
Dr. Ahmad Abd Al-Jabbar Shanshal	Director	Al-Jazira	Formerly of Group 2
Dr. Abdul Halim Ibrahim Al Hajjaj	VP	IAEC	Formerly of Group 2
Dr. Thamer Mawlood	Director General	Al-Tahadi	Formerly of Group 2
Dr. Munqith Hikmat Shawkat Al Qaisi	Deputy Director General	Ibn Yunis/Saad Center	Formerly of Group 2
Dr. Saad Shakir Tawfiq	Director General	Al Khazin Center	Formerly of Group 2
Dr. Faia Ali-Husayn Berqudar		IAEC	Formerly of Group 4
Dr. Ala Abas	Director General	Diwaniya	Formerly of Group 2
Y.M. Al Jabouri	Director General	Nida	Formerly of Group 3
Dr. Wadah Jamil Rauf	Director	Raya Center	Formerly of Group 2
Ali Hussain Alwan	Director General	Al-Zafh Al Kabeer	Formerly of Group 1/EDC

nel were also moved to the Ministry of Industry and Minerals (MIM), the Electricity Commission, and the IAEC.

- 'Abd-al-Tawab 'Abdullah Al Mullah Huwaysh, former Director of the MIC, confirmed PC-3 scientists moved into the numerous companies in the MIC including Al Razi, Al Zawrah, Al Nida, Um al-Ma'rik, Al Majd, Al-Zahf Al-Kabeer, Al Radhwan, Abu Al Rushd, Al Rayah, al Tahadi, and Ibn Sina. It was Huwaysh's contention that skill sets dictated the placement of scientists.

A senior MIC scientist stated that scientists associated with Iraq's pre-1991 nuclear weapons program were often transferred en masse to one of several MIC companies, including the Al-Raya Company and the Ibn Sina Company. These scientists would participate in research projects that would help them maintain their knowledge of their former nuclear weapons research. An ISG site visit to Ibn Sina corroborated such activities, including phosphoric acid purification and lanthanide separation by ion exchange and solvent extraction—processes similar to those required for uranium extraction and reprocessing techniques (see Figure 33).

The reassignment of scientists to nonnuclear projects over the years is also reflected in comments provided by IAEC Chairman Al-Janabi to ISG. Janabi claims that he asked Saddam around March 2001 to gather former IAEC scientists and researchers at the IAEC in Tuwaitha. However, Saddam told Al-Janabi not to ask for them at this time because the MIC needed these scientists for other programs.

In the immediate aftermath of Operation Desert Storm, Iraq also tried to save some of its equipment and capability from the PC-3 program as part of a denial and deception effort. In some cases, preservation of the equipment and capability may have been intended for eventual reconstitution of a nuclear program but also were used to support other nonuclear programs. The "Denial and Deception" program included the movement and/or destruction of equipment, movement of personnel, and destruction of facilities. Many actions were directly related to the degree of incrimination provided by equipment and facilities with respect to NPT violations. Table 7 indicates the deliberate destruction of some facilities by Iraq. Table 8 indicates some of the movements and actions undertaken by Iraq with respect to the uranium conversion program equipment.

- According to Iraq's FFCD, "An order was issued to PC-3 and EDC [Engineering Design Center] at the end of May 1991 to hand over the main equipment and non-nuclear materials (that indicate NPT violation) of the nuclear program to SAP [Security Apparatus for the Protection of Military Industrialization Establishments] for protection.… The order covered only the equipment and nonnuclear materials which indicated violations of NPT." "The main equipment and nonnuclear materials of the nuclear program were transferred through SAP to the army from the different sites during the period May 28, 1991 until June 9, 1991." "The purpose of the above equipment and nonnuclear materials transfer was to avoid detection by IAEA Action Team-2."

- Iraq's declarations provide many examples where it salvaged equipment from sites formerly associated with its pre-1991 nuclear weapons program—a move ISG suspects was as much to conceal possible NPT violations as to preserve a reconstitution capability. Iraq's declarations and IAEA inspections indicate that the early 1991 concealment activities resulted in some equipment being damaged or unilaterally destroyed. Ultimately, some items associated with the pre-1991 program were moved to a storage site at Ash Shaykili or utilized at several universities or state establishments.

- In the early years of inspections, Iraq also tried to claim its Al-Athir nuclear weapons assembly site was a materials development center.

The decision to destroy or salvage equipment appeared to have a simple criterion: the degree of incrimination with respect to NPT violation by Iraq. In general, much equipment specific to a nuclear weapons program was to be destroyed, while dual-use equipment was to be salvaged. For example, Tuwaitha Building 64 was severely damaged during Operation Desert Storm. The undamaged plant equipment was salvaged and stored. The unit components that were contaminated with natural uranium were unilaterally destroyed while other general purpose components were retained for subsequent use in nonnuclear activities.

- Another example is the equipment at Rashidiyah. Equipment directly related to the nuclear program was to be destroyed while indirectly related or general purpose equipment was moved to General Establishment for Engineering Technologies

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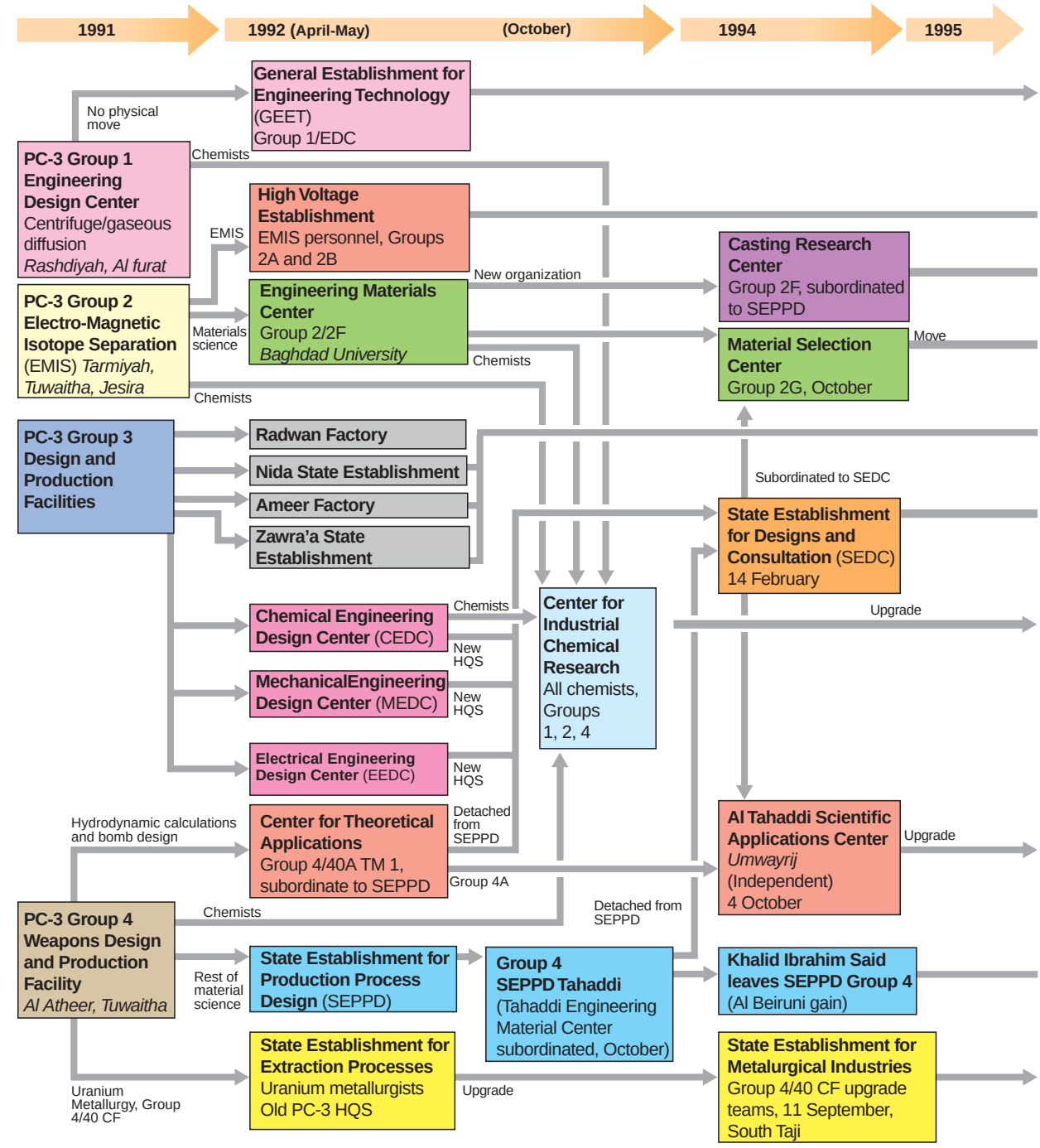

Figure 33. *Evolution of Iraq nuclear weapons organizations since 1991 (Colors indicate organizational continuity).*

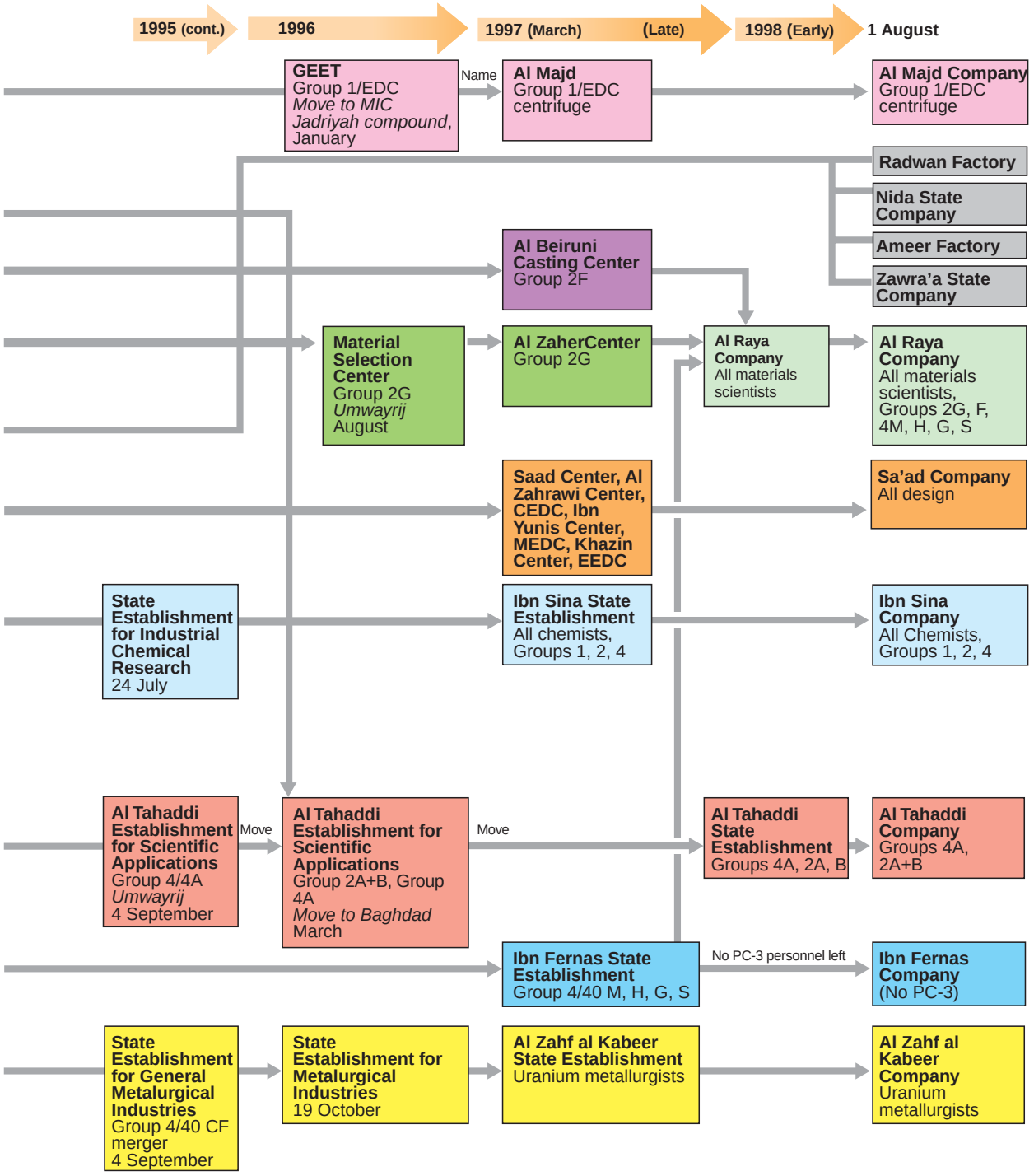

Figure 33. *Evolution of Iraq nuclear weapons organizations since 1991 (Colors indicate organizational continuity) (continued).*

(GEET) storage. Iraq did not consider it relevant to declare these stores because Iraq considered this equipment neither nuclear nor nuclear related. Some of the equipment and materials were used in the reconstruction program while others were given to some establishments in need of the equipment.

In the early 1990s, Iraq retained residual capabilities that could support a nuclear program by adapting personnel and dual-use equipment to nonnuclear activities but display the generic capabilities applicable to their previous nuclear-related efforts. In the full accounting of program equipment, some equipment could only be accounted for as "lost."

- According to one high-level scientist, workers at PC-3 sites were instructed to remove materials, equipment, and documents from their workplace prior to the UN inspections in May 1991. The laboratory from the Tarmiya EMIS uranium enrichment site was used to outfit a laboratory at the University of Baghdad College of Education (Adhamiya district) where research on Freeman ion sources was continued. Other researchers at Tarmiya also built a vacuum system laboratory at Baghdad University (Jadriya district).

- An example of "lost" equipment includes equipment at Al-Athir that was shipped for destruction. Although some boxes were destroyed by the army, the remaining boxes were returned. The items that were not found in these boxes and parts of which could not be located at the destruction sites were considered to be lost during evacuation.

IAEC Modernization

Interest in the IAEC and Intervention by Saddam Husayn

From at least 1999 onward Saddam became increasingly interested in the activities of the IAEC and began holding regular meetings with representatives of the IAEC. Saddam also began to personally intervene in matters related to the IAEC, ranging from internal personnel issues, to prompting other organizations to work with the IAEC and utilize the IAEC's scientific capabilities**.** In late 1996, Saddam agreed to the Oil-for-Food program, resulting in significant fund, which he was able to use to bolster his scientific base.

- A former scientist at the IAEC spoke of many scientists leaving the IAEC in 1999 because conditions were so poor. The scientist claims that Saddam personally intervened, beginning in 1999, to improve conditions and raise salaries. He also made what the scientist called "a blanket rule" at this time forbidding scientists from leaving their posts.

- Dr. Huwaysh recalled that in 2001 and 2002 the frequency of meetings between Saddam and Iraqi nuclear scientists increased. During the same time frame, Saddam also issued a Presidential Order to the President of the IAEC, Dr. Fadil Al-Janabi, that he should keep nuclear scientists together at the IAEC in order to pool their skills and have them available when needed for starting numerous new projects. Dr. Huwaysh did not know the specific details of any of these projects.

- Dr. Huwaysh also recalled that, circa 2000, when Saddam found out that former nuclear workers in the IAEC were not being paid as well as those in the MIC, he met with Al-Janabi, initiated raises in their salaries, and instituted a bonus scheme.

- A former MIC official stated that, in January 2002, Saddam issued an order requiring the MIC to cooperate with the IAEC and to implement projects in the areas of physics, machining, and electronics.

Saddam also began to take an increased interest in the welfare of former nuclear scientists in the MIC. Dr. Huwaysh stated that in 2000 Saddam began asking about the welfare of former PC-3 scientists within the MIC and referred to them as "my people." Saddam, a former IAEC Chairman in the mid-1970s, reportedly made it clear that he cared greatly about the former nuclear program and began showing a renewed level of interest in it at this time.

Increased Funding and Publicity of IAEC Activities

In the last years before the war, the IAEC received increased publicity for its achievements and a larger budget, prompting many former PC-3 scientists to want to return to the IAEC from the MIC. This was partly due to the perceived improvements in conditions and salary increases. More money also became available to the IAEC through direct funding by Saddam**.**

- The former MIC Minister recalled the budget of the IAEC increasing in 2001/2002 and that Saddam overruled the Finance Minister's opposition to the budget increase. The MIC Minister did not know by how much the budget increased.

- A former IAEC scientist stated that the IAEC budget increased through the 1990s in line with standard inflation but then increased sharply beginning in 2000.

Infrastructure Improvements at the IAEC: The Modernization Project

New computer numerically controlled (CNC) machine tools sought for IAEC's Tuwaitha workshop in what has come to be known as the Modernization Project were not subject to nuclear export controls and were reported as required by the UN's Ongoing Monitoring and Verification (OMV) Regime. In 2001/2002, following meetings with Saddam, Al-Janabi and Dr. Khalid Ibrahim Sa'id embarked on a plan to improve the machine tools workshop at Tuwaitha and supply it with new machines—an activity that was not completed before the war.

- Former MIC Minister Huwaysh recalled that in 2001, Al-Janabi and Dr. Sa'id approached him and requested support for a special project. He was not told the nature of the project but learned that it involved the procurement of very precise machines. Huwaysh, after consulting with Saddam, agreed with the understanding that the purchase would be conducted through MIC's Al-Basha'ir Company.

- Due to reluctance on the part of international dealers to sell to the IAEC, Al-Janabi used the MIC to purchase the machines to conceal the fact that the IAEC was buying the machines. Al-Janabi also recalled that the contract for the high-precision machines was between the Al-Badr Company and a Taiwanese supplier. The Deputy Director General for Engineering was responsible for machine selection. Sa'id assisted in the project because of his extensive experience within the IAEC and his good managerial abilities. Sa'id's main role was to coordinate with the Finance Ministry to receive approval for the purchases and draw the hard currency from state funds when necessary.

- Al-Janabi also stated that he approved the purchase of the machines as part of an initiative to modernize the IAEC. He believed the machines were more accurate than Iraq's existing capability.

- While there is no question that the IAEC pursued these machines, there are conflicts in the information regarding the actual purchasing agent, the Al-Badr Company or the Al-Basha'ir Company. ISG believes that it is most likely the specifications and order were made by the Al-Badr company, on behalf of the IAEC, and the order was placed through the Al-Basha'ir Company, which was the actual purchasing agent.

Dr. Huwaysh told ISG that, although he was not explicitly aware of what was being purchased, in his opinion the machines that the IAEC were buying were more accurate than those at any MIC owned companies and that the IAEC was supply-

Modernization Project—Machine Tools

Machine Type	*Model*	*Country of Origin*	*Cost (US $)*
CNC Milling Machines	2 x MCV- 600E	Taiwan	160,020
Surface smoothing	1 x KGC-84MSI	Taiwan	83,717
Wire-Cutting Machine	1 x A300	Taiwan	155,228
Spark Machine	1 x M50F	Taiwan	86,427
CNC Milling Machines	2 x MCV-1200	Taiwan	225,000
CNC Copy Milling Machine	1 x VTC-1400 CTC	Taiwan	395,000
Lathe Machine	1 x MT52S	Taiwan	90,000
Lathe Machine	1 x MT52L	Taiwan	95,000
Vertical Lathe Machine	1 x VL-12	Taiwan	268,926
Plasma-Cutting Machine	1 x 315A ROSSA	Bulgaria	165,400
3D Measuring Tool	1 x 3D DEA10	Italy	115,000
Sorting Machine	1 x MI-400	Unknown	Unknown
Lathe Machine	TNC-30NL	Unknown	Unknown
Punching Machine	Unknown	Taiwan	67,000
Laser Pointed Drill	Unknown	Spain	67,000

ing its workshop with high-precision machine tools. Furthermore, he stated the Modernization Project was classified to the extent that even he was not made aware of its details. This compartmentalization was evident at the top levels of the Regime, including Saddam, who personally verified that the MIC Minister was to assist the IAEC. However, none of the sources debriefed have been able to explain why the MIC Minister was excluded from the technical details of the project.

- Dr. Huwaysh's assertion that the purchase of the machines was a secret program is puzzling, given that the machines were reported to the UN/IAEA and were thereby subject to inspection. Other sources have commented that it would have been impossible for Dr. Huwaysh not to know what was being procured because it was his organization doing the procurement and that the project may not have been classified. A high-level Iraqi scientist stated that these high-precision machines were installed at Tuwaitha, and information regarding the machines was provided to the UN and IAEA in the declaration given in December 2002.

In contrast, former IAEC employees directly responsible for the selection and installation of the machines told ISG that the machines the IAEC purchased were the same as those already operating at Badr and were not particularly high precision. The same former IAEC employees went on to suggest that the machines were, in fact, of poor quality, cheaply made, and were prone to break.

- Former IAEC employees, Diya' Jalil Husayn and Zuhair Al Yassiri, selected the machines based on generic workshop requirements. The majority of the machines were Asian in origin, and they were described as "cheap Taiwanese machines."

ISG also received conflicting information regarding the specific use of the machine tools workshop

beyond general machining capabilities. The former President of the IAEC described the procurement of the machines as the development of Iraq's "non-nuclear scientific infrastructure." The machines would enable the IAEC to create molds and manufacture specialty parts for machinery in-house rather than outsourcing the work.

- A former IAEC employee with close ties to the project told ISG that the machines were to be used to manufacture equipment for use by the IAEC in R&D (primarily for the Physics Directorate) and were not to be used for the manufacture of items for outside organizations.

- A senior executive in the MIC described how the Center for Mechanical Design was to receive the equipment, reverse-engineer it, and send it to the Badr, which would then produce high-precision tools from it.

Perceptions the Regime Was Preparing for Reconstitution of the Nuclear Program

Saddam's increased interest in the IAEC and publicity of IAEC achievements, increased funding, and infrastructure improvements prompted Dr. Huwaysh to speculate that Saddam was interested in restarting a nuclear weapons program.

- Dr. Huwaysh was suspicious this procurement was part of an attempt to restart the nuclear weapons program because both Janabi and Sa'id were part of the pre-1991 nuclear weapon program. He also was suspicious of Sa'id's involvement because Sa'id was close to retirement. Furthermore, Dr. Huwaysh knew that high precision machines are needed to make centrifuges, although he admitted he only had the general notion of the capabilities of the machines.

- Dr. Huwaysh believed these factors may have been an indication that by 2000 Saddam had run out of patience waiting for sanctions to end and wanted to renew the nuclear program, though he could offer no concrete evidence to support this view. Alternatively, Dr. Huwaysh speculated that Saddam may have had a small group of people advising him on nuclear power issues, although Dr. Huwaysh had never heard about it.

Alternatively, Al-Janabi says he approached the Presidential Secretary, 'Abd Hamid Mahmud Al-Khatab, in late 2001 with a proposal to modernize the IAEC in order to develop Iraq's nonnuclear scientific infrastructure. Khatab approved the idea and authorized the use of state funds through the Ministry of Finance. It was commonly understood that Khatab spoke for, and with the authority of, Saddam. As a result, Janabi began a broad effort to raise salaries and modernize departments, including procurement of the CNC machines.

- Other interviewees also were consistent in suggesting the new equipment was needed to fix a degraded, or lost manufacturing capability at Tuwaitha. A former vice president of the IAEC stated that the purchase of these machines was not intended to modernize the IAEC's manufacturing capability, but to re-create practical research capabilities.

- A MIC scientist working at the IAEC glass workshop described the machine purchase as a means of improving the machines of the tool room workshop because the existing machines in 2001 were no longer functioning or not functioning properly.

- Dr. Huwaysh also has quoted Saddam as saying "We do not intend or aspire to return to our previous programs to produce WMD, if the Security Council abides by its obligations . . . ."

IAEC Work on Neutron Generators

ISG has found no evidence of neutron generator or initiator research as part of a post-1991 nuclear weapons development program. Programs involving a French-supplied neutron generator are probably related to ongoing IAEC improvement efforts, which started by 2000.

- In 1984, the IAEC acquired a large neutron generator from a French company. In 2002, targets were bought for the neutron generator from the German

company Siemens because the United States would not sell to them. The generator has been used for research projects related to geology, food, and environmental studies. As of May 2003, some parts of the neutron generator had been looted. Iraq also had small Americium-Beryllium and Plutonium-Beryllium neutron sources.

- Dr. Shaker Al-Jabouri, Director of the IAEC Nuclear Physics Department from 1992 to 2003, was in charge of the neutron generator at Tuwaitha as well as being a professor in the Department of Physics, University of Baghdad, from 1987 to 2003. He supervised numerous graduate students at the University of Baghdad whose theses included "Measurement of Neutron Activation Cross Section Using Neutron Angular Distribution Produced by 14 MeV Neutron Generator" and "Calculation and Measurement of Neutron Cross-Section for Energy Range 0.5 to 3 MeV." These studies indicate Jabouri and the University of Baghdad remained involved in material cross-section work—a subject area with applications to civil radiological programs and nuclear weapons research.

- According to translated Iraqi documents—specifically a 2002 memo from Jabouri—a neutron generator was used in his laboratory in several postgraduate nuclear activation projects. The projects included radiation effects on materials, development of control systems, design of a rotating target, design of a magnetic analyzer, and design of an ion source.

- The IAEC/Physical Research and Materials Directorate/Nuclear Applications Section carried out various research activities using a neutron generator and related technologies. ISG has not been able to identify any neutron generator activities by this organization related to a nuclear weapons program.

University Programs

Universities played a supporting role to preserve Iraq's nuclear knowledge base. While ISG has found no information that universities supported any pursuit of nuclear weapons, ISG did find that universities offered a haven for some former PC-3 personnel and dual-use equipment after Operation Desert Storm and were being reestablished as a source of knowledgeable support for the IAEC and MIC after 1999.

ISG found that Iraqi educational institutions accepted equipment salvaged from the pre-1991 program, but we are unable to show that universities played a role in any renewed Iraqi nuclear weapons effort. The following are examples of instances where Iraqi institutions received equipment from the former nuclear weapons program:

- **Tuwaitha.** Iraq admitted that educational institutions that received equipment from Tuwaitha for storage and/or incorporation include Teachers Training Institute, Institute of Technology in Zaafaraniya (student dormitories in Al-Waziriya), University of Baghdad (dormitories in Jadiriah), and the College of Physical Education.

- **Tarmiya.** Iraq also declared that educational institutions that received equipment from Tarmiya—such as general laboratory devises and spare vacuum system parts—for storage and/or incorporation include University of Mustansiriya, University of Baghdad (College of Science), Saddam University (College of Science), and the Institute of Technology (Department of Chemical Industries).

- **Al Atheer.** The Al Karama secondary school and Al-Anwar primary school received equipment evacuated from Al Atheer around February 1991, according to Iraq's declarations. Similarly, some equipment not associated with any NPT violation was transferred to Saddam University and the University of Technology. According to Iraq's declarations, the Babil University also received an unidentified number of boxes of unidentified equipment—allegedly most of which contained damaged and mixed components from the former nuclear weapons program at al Atheer.

- **Rashdiya.** The University of Baghdad also received equipment and materials from the former centrifuge program.

In the early 1990s Iraqi nuclear program personnel found temporary homes in educational institutions—moves that occasionally involved shifting of groups of scientists from the former weapons program. University programs offered a means to preserve the existing knowledge base by providing an opportunity for former PC-3 personnel to pass on their basic, fundamental knowledge to new generations of scientists.

- According to one high-level scientist, workers at PC-3 sites were instructed to remove materials, equipment, and documents from their workplace prior to the UN inspections in May 1991. The laboratory from the Tarmiya EMIS uranium enrichment site was used to outfit a laboratory at the University of Baghdad College of Education (Adhamiya district) where research on Freeman ion sources was continued. Other researchers at Tarmiya also built a vacuum system laboratory at Baghdad University (Jadriya district).

- Another high-level scientist confirmed that staff from PC-3 projects at Tuwaitha received the same instructions. As a result, Dr. Qais Abdul Hamin established Electronics Laboratories and Departments for Power Electronics, Instrumentation, and Distribution Control at the Technical University in Baghdad with equipment and staff from PC-3. A laboratory was established at the University of Baghdad led by Dr. Hamid Al Mundiri and staffed by PC-3 materials scientists. A Surface Inspection and Measurement Laboratory was established at the University of Baghdad led by Dr. Nabil Ramu.

- Documentary information collected by ISG indicates that Dr. Saadi Ja'far Hasan left Al Atheer in June 1991 and transferred equipment to Saddam University. Ja'far taught atomic physics, nuclear physics, nuclear spectroscopy, and advanced physics. The equipment was used to establish an atomic physics lab for second year students, a preliminary lab for undergraduates/third-year students, and a more advanced lab for fourth-year students.

Through the 1990s, educational institutions shared some personnel with MIC and the IAEC—activities that seem to be motivated most by the need for former weapons program officials to find new employment, but steps that inherently preserved access to scientific knowledge and capabilities from the pre-1991 program. Officials have indicated that former PC-3 scientists were unhappy with MIC employment, dissatisfied with IAEC pay, and used the universities as a way to supplement pay and create more interest in their work.

- According to Huwaysh, most PC-3 personnel were kept in the MIC after 1991. However, some nuclear physicists went to the universities because there was no nuclear work for them in the MIC.

- Al-Janabi stated that "most IAEC researchers also taught at universities or advised doctoral students, both for scientific and financial reasons." However, there was no placement program to place IAEC scientists into university positions. Each scientist had to find a university position on his own and was permitted to work only one day a week at the university. Al-Janabi also stated that the IAEC provided approximately one million dinars per year to universities for research and that, during the universities' summer break, many faculty members worked at the IAEC or the MIC to make additional money.

- According to Dr. Nafi 'Abd Al-Latif Tilfah, Dean of Baghdad University's Institute for Laser and Plasma Studies, post-1991 laser research was conducted at the Baghdad University Institute for Laser and Plasma Studies, the Baghdad University of Technology, Mustansiriyah University, and the al-Razi Company. While most of the research was paid for by the universities and the Ministry of Higher Education, the Al-Razi Company—which was subordinate to the MIC— also financed some postgraduate research projects. A number of key scientists from the pre-1991 laser uranium enrichment effort—including the head of that effort, Dr. Faleh Hamza—worked at Al-Razi after the 1991 war.

Reporting indicates the relationship between the universities and the MIC and IAEC was relatively ad hoc until the late 1990s, until efforts were made to send MIC and IAEC projects to the universities. With Saddam's support, MIC and IAEC dramatically increased joint university activities. The influx of funds would not only bolster a deteriorating university system but would also tend to focus university programs on MIC and IAEC issues. The result would be a new generation of scientists with a focus and understanding of MIC and IAEC pursuits.

- According to Huwaysh, cooperation between the MIC and Iraqi universities was largely a formality prior to 1999. Huwaysh claims that in 1999, he called a meeting of all Iraqi university heads to discuss the loss of professors to higher-paying industry jobs, which was crippling the university system. As a result of the meeting, he approved all professors to perform research for up to four MIC contracts each. Saddam liked his initiative so much that in late 1999 he ordered each of the ministries, including the IAEC, to implement a similar program of sending research projects to the universities. As a result, MIC-sponsored research projects in Iraqi universities jumped from approximately 40 in 1997 to approximately 3,200 in 2002.

- According to Iraqi declarations, the Institute for Training and Employee Development in the IAEC's Scientific Policies and Programs Department is described as providing a variety of coordination activities with universities. This includes both the opportunities for scientists to take advantage of university activities as well as the opportunity for university personnel to support IAEC facilities.

The historical relationship between former PC-3 scientists and Iraqi universities suggests that some nuclear-weapons-related research could have taken place within the universities, although ISG has uncovered no direct information that such work was under way. A number of highly placed individuals in the former Regime have stated that no nuclear-weapons-related research took place at universities. However, some research activities display obvious dual-use application to nuclear weapons development.

- **Laser Research.** Baghdad University's Institute for Laser and Plasma Studies researched and developed many types of lasers, including Copper-Vapor Lasers (CVL) as recently as 2002. This research was done in conjunction with al-Razi, with the stated purpose of research and development in laser targeting systems and directed energy weapons. CVL technology is relevant to Atomic Vapor Laser Isotope Separation (AVLIS) as well as many civil applications, and at least one of the researchers involved in this project was Dr. Faleh Hamza. ISG believes that this work does not indicate a reconstitution of a laser isotope separation program but offers an opportunity to preserve CVL knowledge and capabilities that could support future reconstitution. ISG has also uncovered reporting that indicates there was a prohibition of continuing nuclear weapons work including laser isotope separation.

- **Tarmiya Equipment.** ISG interviews of a high-level Iraqi official indicate that equipment from the PC-3 EMIS facility at Tarmiya was moved to Baghdad University after the 1991 war and prior to the start of intrusive inspections. At the university, studies reportedly were done in Freeman ion sources, and the Tarmiya employees built a vacuum system at the university. This work—while relevant to EMIS technologies—does not indicate a reconstitution of such a program, but offers an opportunity to preserve knowledge and capabilities that could have supported future reconstitution.

- **Other Examples.** A group of PC-3 materials scientists set up and staffed a laboratory at the University of Baghdad with equipment from Group 2FE. The laboratory was led by Dr. Hamid Al Mundiri. A surface inspection and measurement laboratory was also set up at the University of Baghdad and was led by Dr. Nabil Ramu. This laboratory later worked on stealth technology. Alternately, the head of PC-3 Group 2E attempted to set up a programmable logic control laboratory at the technical University of Baghdad, but the university refused to accept the laboratory because of the risk of being discovered by IAEA inspectors. All of these examples represent maintenance of knowledge and capabilities, but ISG has found no evidence that the laboratories continued work in support of a nuclear weapons program after 1991.

Hidden Enrichment Technology

Since Operation Iraqi Freedom, two scientists from Iraq's pre-1991 nuclear weapons program have emerged to provide ISG with uranium enrichment technology and components, which they kept hidden from inspectors. In August 2003, a former EMIS scientist told ISG during an interview that he had taken material and equipment that was related to EMIS and hid them in various places near his home in the 1990s. The scientist had not been specifically told to do this but believed his supervisors were cognizant of his actions. He chose items to hide that could be used in future reconstitution of the EMIS program. The scientist turned over to the Coalition a broad range of items that had been withheld from the UN inspectors, including technical reports on EMIS, a collection of foreign EMIS-related patents, a mass spectrometer, blocks of high-purity graphite, high-purity tantalum shielding sheets, and an indigenously designed collector piece from inside the EMIS machine. Some of these items are shown in Figure 34.

The former head of Iraq's pre-1991 centrifuge program also retained prohibited documents and components in apparent violation of the Regime's directives. Though this activity was isolated, it also had the potential to contribute to a possible restart of Iraq's uranium enrichment programs.

- In mid-2003, Dr. Mahdi Shakar Ghali Al 'Ubaydi provided Coalition forces with centrifuge components and a complete set of workable centrifuge blueprints, which he, reportedly, had hidden at his home for the purpose of reconstituting the centrifuge enrichment program after sanctions were lifted.

- Al 'Ubaydi reportedly hid these items in 1991, a move approved later that year by Husayn Kamil—Saddam's son-in-law and former head of Iraq's WMD programs. Qusay reportedly confirmed the order in 1992, but al 'Al 'Ubaydi had not been contacted since. ISG is not able to show that the Iraqi Government continued to be aware of Al 'Ubaydi's concealment activities or otherwise planned to use them as part of a plan to reconstitute the centrifuge program.

- According to a former PC-3 nuclear design scientist, he was surprised when he learned that Al 'Ubaydi had retained centrifuge program documents in his home. The scientist was very skeptical that orders were given to retain the documents and material associated with the former centrifuge program.

- Former Presidential Scientific Advisor Amir Hamudi Hasan al-Sadi stated that any Iraqi scientists that kept nuclear related material at their homes were acting on their own.

Figure 34. *Items stored at former EMIS scientist's home—high-purity tantalum sheets (left), technical papers (center), and mass spectrometer (right).*

Survey of Structures at Tuwaitha Nuclear Research Center

Scope

This report presents the findings of an Iraq Survey Group (ISG) survey mission between 20-22 November 2003, designed to clear all buildings at the Tuwaitha Nuclear Complex prior to their use by Ministry of Science and Technology (MOST) personnel. The survey investigated the buildings' probable research functionality, looked for any nuclear relevant or UN-labelled equipment, exploited documentation/ electronic media, and determined the buildings physical status. The mission was one of the larger activities undertaken by ISG and the largest undertaken by ISG's nuclear team. This site was the most important to Iraq's nuclear research program and was one of hundreds of sites examined by ISG. The comments cited under the Team sections are from team notes taken on site and should not be considered authoritative, but indicative of the type of information collected.

Summary

- The status of all buildings and structures at the Tuwaitha Nuclear Research Center, known at 22 November 2003, has been determined (see Conclusions and Annex B).
- Certain structures pose hazards from a radiological and unexploded ordnance point of view. These structures were not entered, and the precise hazards were not determined (see Annex D).
- A quantity of UN-labeled equipment was identified as well as other dual-use equipment including Anderson Samplers (see Results section and Annex E).
- Some 66 boxes of documentation and a large quantity of electronic media were collected and subsequently handed over to ISG for translation and exploitation (see Main Survey Procedure section and Results).
- The mission completed its objectives and at present ISG has no plans for further exploitation at the complex. However, it is possible that, if further information comes to light, ISG may need to revisit Tuwaitha.

Introduction

Tuwaitha is located on the east bank of the Tigris River, 18 kilometers southeast of Baghdad, 2 kilometers southwest of Zaafaraniyah, and approximately 1 kilometer west-‑southwest from a two-lane improved highway. The facility is protected by large berms that surround and divide it into four distinct areas: the former Soviet Reactor Complex and Administration/ The Agricultural and Biological Research Center (TABRC) area in the northern quadrant, the former French Reactor Complex area in the eastern quadrant, the Research and Development area in the western quadrant, and the former Italian Laboratory area in the southern quadrant. For the purposes of this survey, the area within the berms was divided into five zones, A to E; the area immediately outside the berms was zone F; and the wider area surrounding the complex was zone G. A workshop facility near the site entrance was zone H, (see Figure 36).

ISG representatives were asked to produce a series of maps from imagery to support the mission as there had been a number of differing building numbering schemes; these were rationalized into the existing building numbering system used as a reference standard for the mission. The comprehensive nature of the products assisted greatly in accomplishing the mission.

The mission was conducted in a number of stages. Initially, a series of consultative meetings were held. These accumulated available knowledge of the Tuwaitha site. They were followed by a two-day video reconnaissance (VR) of the site with the aims of identifying any unknown hazards and to assist in the planning of a final document exploitation (DOCEX) mission as well as the main survey (MS) .

The initial stage of the main mission was also assisted by a meeting with Black List #99, Dr. Fadil Muslim Abd Al-Janabi, current head of the Iraqi Atomic Energy Commission (IAEC), which had its

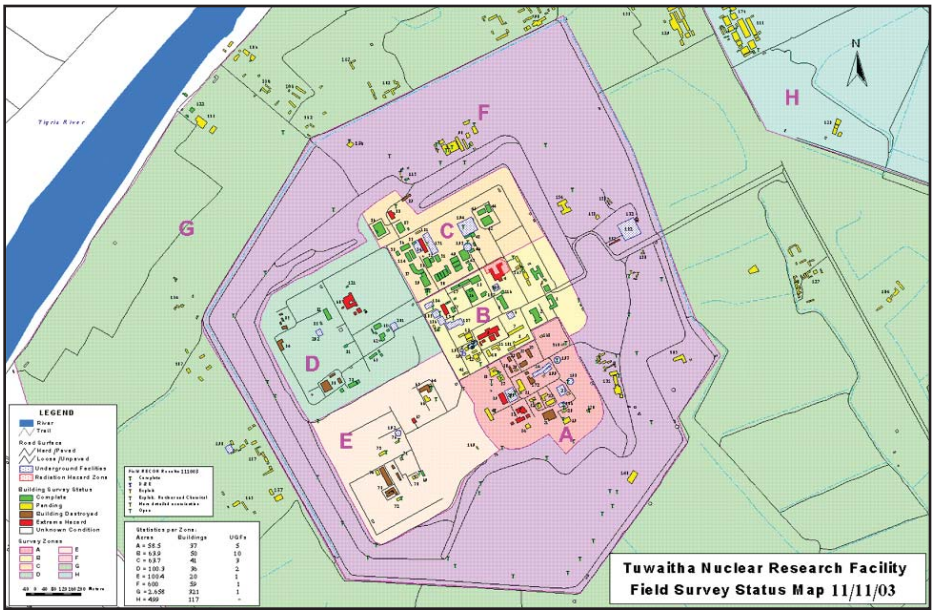

Figure 36. *Tuwaitha Complex showing survey zones.*

headquarters at Tuwaitha. Dr. Fadil was asked about the location and functionality of various assets at Tuwaitha, and his information was assimilated into the list of targeted buildings for Tuwaitha. He was also asked, and he agreed, to accompany the author to the Tuwaitha site and provide information that was of significant assistance to the planning of the mission.

Prior to the VR, a target list of buildings was compiled, and those facilities (surface and subsurface), where it was safe to do so, were visited during the VR. The finalized target list was used as a database to record the mission progress.

The video reconnaissance (VR) of a number of buildings at the site was undertaken on 5-6 November 2003 using four multidisciplinary teams to cover the site quickly on a zone-by-zone basis. Analysis of the videotapes and commentary produced is included at Annex C, which was instrumental in the detailed planning of the main mission.

During the VR, an optical spectrometer and Andersen samplers were identified, and a one-day mission was mounted to recover that equipment and to carry out a DOCEX on three target buildings on 11 November 2003. The one-day mission also provided the facility to test some of the procedures planned for the main survey. Following analysis of the VR results, the buildings' target list was revised, and relevant discipline subject matter experts (SMEs) lead teams were tasked to review those buildings in the main survey (MS).

The MS was conducted by moving 61 ISG personnel, SMEs, and force protection staff to create 5 teams with delegated responsibility for a set of buildings. The teams lived on site for 3 days in order to avoid force protection risks of daily travel.

The teams were tasked to pretriage any documents in their buildings and the team leaders were asked to sign preprinted sheets to confirm the status of each building for ISG purposes. Over the 3 days of the MS duration, an up-to-date list of building status was compiled, which is presented as Annex D to this document.

Factors Affecting the Survey

All buildings identified at the Tuwaitha complex whose status was uncertain were included in the target list as pending survey. Buildings that were hazardous in respect of their structural status from bomb damage, radiological, or other reasons were not entered and were marked as a hazard on the target list. Areas or underground facilities (UGFs) flooded with water possibly contaminated with coolant from the damaged reactors were also not visited. Where possible, visual inspection was made using a video camera. Sealed containers were examined by drilling small holes and inserting optical fiber-viewing aids into the container to examine the contents and, if necessary, the provision of larger holes to enable SME access.

Main Survey Procedure

DOCEX Procedures for Combined Media-Processing Center, Baghdad (CMPC-B)

It was important to use the limited linguist resource effectively in the triage of documents and to minimise the duration of this process. Consequently, a new list of mission-relevant keywords was produced and procedures introduced to locate precisely any media identified as sensitive. The teams were told to collect any form of electronic media and personnel files if seen. Blueprints and management diagrams were also targeted.

Mission planning allowed one CMPC batch number per building; document boxes were identified by: batch number, building number, and serial number of box. Separators were used to link documents to room numbers. The boxes were assigned a starting batch number of 3326 – 2, which would increment with building number so, for example, the N^{th} building would be 3326 – (N + 1).

A US Army Major was given the responsibility of monitoring and, if necessary, driving the DOCEX part of the mission. A US Air force LTC was asked to run the Command Post (CP) and to issue building targets to the teams as required.

The mission was conducted by fielding five survey teams, all of which were led by a nuclear technology discipline SME. Four of the teams contained a linguist, a second discipline SME, a document gatherer, and a force protection person. On arrival on site, each of the teams was allocated a large DOCEX task and a caution task. Following the clearing of those buildings, the teams were allocated buildings on a team-availability basis designed to work around the outstanding buildings of the Tuwaitha inner zones on a clockwise basis. The mission was controlled via the CP and the target list updated as the building status survey proceeded. A mission log of all significant events was maintained by the CP.

Four teams were deployed in zones A to E; a fifth team, led by the Author, surveyed zones F, G, and H with the aim of dealing with the more difficult building targets, until such time as it could be supported by other teams on an availability basis.

Using the given definitions (found in Annex A), building status was updated from pending or caution to either clear or triaged, and the presence of any mission-relevant equipment similarly recorded.

Results

It is quite possible that some sensitive information will be forthcoming once all exploitation is completed. However, the primary results of the mission are:

- Some 66 boxes of documentation and a quantity of electronic media were found, which were handed over to CMPC-B for exploitation post mission.
- Three Andersen Sampler bases and two tops were recovered.
- A quantity of UN-labeled equipment was identified. The information obtained was included in and used to update the "Summary of Known UN Tagged Equipment" presented at Annex E.
- All personnel completed the mission safely and free from any radiological contamination.

[ISG Note: Further exploitation produced no additional information to contradict these results.]

Discussion

A group of unknown Iraqis were spotted by Team Bravo loading documents and equipment onto a vehicle on the morning of 22 November. Detail is provided under Team Bravo comments in Annex B.

The initial planning commenced with a list of approximately 206 structures; 58 of these had been previously surveyed and cleared by ISG video reconnaissance and/or previous missions. Furthermore, 28 structures had been previously destroyed, 8 deemed hazardous, and a number were not applicable for exploitation, such as air defense sites, and areas outside the Tuwaitha complex region. As such, 93 structures remained pending for exploitation. During

the main mission, these 93 structures were surveyed. ISG members also returned to a number of previously surveyed and unidentified structures. In all, the main three-day mission surveyed 106 structures, all but two were certified as either clear or triaged.

The buildings that were not cleared were the library (Building 42) and the fire station (Building 151). In the case of the former, the quantity of documents is vast, and all survey teams as they completed their normal task list, were dispatched to the library to facilitate the process. The teams were specifically instructed to target Ph.D. theses and to search for unusual document positioning or storage. Using this process, a best endeavors attempt was made to clear the library.

Building 151 is the fire station, which is operational. During the VR, a room full of binders was identified, and a team was dispatched on the last day of the MS to triage the binders. Initially, there was some difficulty in identifying the location of the room, and the fire station personnel denied the existence of any such room. The team withdrew to check their facts and then returned and identified the room, which was secured by a locked glass paneled door. Staff claimed that the material was commercial, belonged to the MOST, and that they did not have a key. They offered to contact MOST to ask for a representative to appear and give access.

After some discussion it was decided to approach MOST via ISG in order to gain access to the room as the team had no wish to force entry to an operational facility or indeed to damage one of the few undamaged buildings at Tuwaitha.

Postmission Activity

A mission was set up to go to Tuwaitha on 2 December 2003 with the aim of gaining access to the room of documents (Building 151). The party arrived at approximately 0815 and asked for MOST to be contacted for a keyholder to attend and open the door. After some discussion it was agreed to gain access to the room, and a full triage of the documents was undertaken. Prior to entry, a series of photographs was taken to verify the status of the room, and this was repeated after the door was secured to demonstrate that no damage had been caused to the room or its fittings.

The records were drawings relating to the Tammuz reactor with little more recent than 1988. Nothing of significance to ISG was found, although a few documents were taken for further exploitation.

Another locked room containing documents was also entered and a full triage undertaken, using the procedures mentioned above. Again, nothing of significance to ISG was found although a few documents were taken for further exploitation. In view of the physical condition of the documents, covered with dust and vermin droppings, it was evident that the documents had been undisturbed for some time and no attempt had been made to introduce other documents into their content. Building 151 complex was considered clear.

Postmission action was also required on a number of issues, specifically:

- UN-labeled equipment.
- Unidentified equipment.
- Testing of samples collected.
- Use of the iridium pellets.
- Document referencing “heavy water.”

Note: These issues have since been resolved and found to be of no concern.

In view of the physical hazards at the Tuwaitha site, the planning detail, terminology, and methodology required to minimize risk to ISG personnel may be used as a template for future ISG missions to complexes of this nature.

The mission has demonstrated that ISG is capable of planning and undertaking the most complex of technical missions. The ability to mount a mission of this nature in such a hazardous area as the Tuwaitha Nuclear complex, without casualties and with the achievement demonstrated, is seen as a contribution to ISG’s reputation.

Conclusions

Following the three-day mission to Tuwaitha and a postmission visit on 2 December, the status of all buildings and structures known on 22 November 2003 has been determined, and it is suggested that the complex may be accepted as clear on the basis of best endeavours.

Best endeavours implies the best that could be achieved with available resources and equipment. The Tuwaitha site occupies some 20 $km^{2,}$ and there are plenty of places; e.g., under radioactive water in basements or damaged buildings where documents, electronic media, or equipment could be hidden by those determined and where some risk to personnel would be involved in order to retrieve them. Without sound supporting HUMINT, missions surveying hazardous locations would be speculative and difficult to justify.

Future Work

This mission has attempted to incorporate HUMINT support suggesting the presence of hidden documents and equipment. The strongest hints were regarding a Building 6, which has not been found, and in the basement of Building 42/43, which has been burned. If additional HUMINT is forthcoming, then a ground radar survey may be appropriate for the future or the use of other high-tech equipment in order to examine all the flooded basements and water tanks.

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Annex A
Definitions Used by Teams During Survey

Clear Room has been inspected, is empty of mission-relevant items, and is certified by the team leader as ready for hand back to Ministry of Science and Technology. The same category may be used to categorize a building.

Triaged Room has been triaged (documents, or a representative sample of documents in the room has been examined) and is certified by the Team Leader as ready for hand back to the Ministry of Science and Technology. The same category may be used to categorize a building.

IOIC Item(s) of interest identified or possible controlled items(s) (an item that is controlled under Export regulations should have been declared or is a potential sanctions breach). **Action:** still photos taken, Military Grid Reference System (MGRS) geocoords, if possible; relevant ISG Dept. informed; and appropriate action initiated. Details to be entered in comments column.

IOIL Item(s) containing a UN or UNSCOM label. **Action:** still photos taken; use of macro setting to ensure clarity of label details; MGRS geocoords, if possible; relevant ISG Department informed; and appropriate action initiated. Details to be entered in comments column.

IOIU Item or items not identified. **Action:** still photos taken, MGRS geocoords if possible, ISG informed, details fed back to ISG for identification by other SMEs, and appropriate action initiated. Details to be entered in comments column.

IC Items inconsistent with the advertised functionality of the Department or room. **Action:** still photos taken; MGRS geocoords, if possible; relevant ISG Department informed; and appropriate action initiated. Details to be entered in comments column.

Hazard Hazard found in room; e.g., source or chem.

Action **T**eam extracted without further action. Team checked for possible contamination or injury. Details of hazard to be entered in comments column together with note of action taken.

Caution Following the offer and availability of a specialist team from ISG, the word caution was introduced to define a building where it was decided as safe for an exploitation team to enter, provided they were escorted by ISG team.

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Annex B
Team Results

Team Alpha Results/Comments

Building 37

Room 1: Contained motor components and flanges, probably water pumps. Two x Bergeron from Paris UNELEC FA225M4 37kW 50 HP, 4 x smaller water pumps F059675 Vitesse 1485 tpm, Nauteur Mano 31m, Puissance 132 kW. Two x smaller cranes with 2,500-kg capacity, water demineralizer T43401 Bignier Schmidt Laurent (French), made for Technicatome 710027.2 1978.

Figure 37. *Building 37, associated mesh storage area and equipment.*

Figure 38. *Equipment contained in mesh storage area associated with Building 37.*

Room 3: Storage of equipment probably for the Tammuz reactors, secondary equipment. Two x heat exchanges (180 sq m, 1986) of Russian heat exchangers, water demineralizer 1978, Bignier Schmidt Laurent (French), 4 x large (1.25m diameter, 8 m long) distillation columns. Two x columns (0.7-m diameter, 8 m long). Crate of unknown items received from Technicatome; miscellaneous valves and fittings to support these columns.

Room 4: Five x B-9 and B-10 permeators.

Room 6: Cable and electric diagrams for Tammuz 1 and 2 reactors.

Building 163, Connex OUTSIDE Building 37
Contained digital-processing equipment, scalers, multiscalers, integrators, I/O analogue boards, computer data racks, 40-channel high-voltage system. Vacuum pumps; Turbo Vac 1500 from Leybold and Heraeus, Figure 39.

Building 53
Is very close to Building 52 and may be included in that complex. The building is a multifunctional building in terms of chemical and biological functionality and was the subject of earlier reporting by CBIST.

Figure 39. *Container adjacent to Building 37 and sample of contents.*

Figure 40. *Building 53 laboratory-scale process.*

Figure 41. *Spray dryer and other process equipment in Building 53.*

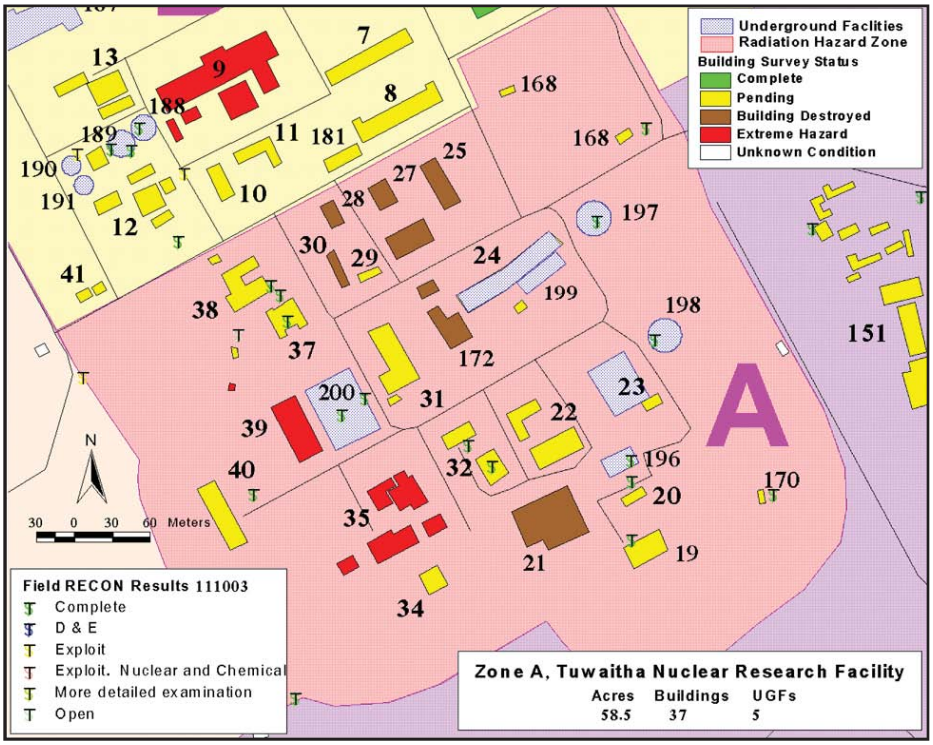

Figure 42. *Tuwaitha Complex—Zone A (status of buildings before the 20-22 November 2003 survey mission).*

Room 1: Chemical-processing pilot plant laboratory, configured for water filtration; plant for clove oil production, well water distillation, and softening of filtered water, distillation of boiler water, and a process for Lipton wax. A substitute, formula, and picture of layout obtained. A production scheme also existed for KCl, NaOH, NaCl and ZnO. Seven items of UN-labeled equipment (Annex E). Other similar equipment and other less sophisticated equipment were present, which did not have labels. It was noticed that certain equipment was missing from the chemical processes mentioned above.

Room 9: Laboratory-scale process for producing new chemical products and product purity testing.

Room 15: Directors office (Mawan Fuad Aziz) had iridium pellets in varying sizes and in vials scattered over his desk. There is postmission speculation over the use of these pellets.

Building 59: Identified as health physics lab but also contained biological and chemical laboratories.

Rooms 1, 2, 29-45: Were health physics, remainder were bio/chem related. Also pilot plant for reverse osmosis system (RO). Some bioresearch was marine oriented.

Room 1: Was where liquid scintillation counter should have been (sampling trays seen); counter had been moved into the bunker next door. Contained smallscale UNSCOM- labeled powder dispenser, model 3433, Annex E.

Room 5, 22 and 29: Rooms for RO.

Room 9: Miscellaneous laboratory-scale bio-related equipment, nutrient media, and chemicals.

Room 15 and 17: Chem/bio laboratories, multiple chemicals all over the floor, photos of scene and listings from cabinets taken.

Room 14: Bacteriology laboratory. Life studies of bio in Tigris River, Legionella and Bacillus Subtillis. Photo reference DSCO1593.

Room 23: Probable autoclave Hirayama HA30 picture.

Room 32: Soil-sampling laboratory. Some unidentified instrumentation.

Photo references DSC01603 - DSC01631 and DSCO 1565 – 1593 1594 to 1600. Some laboratories had been looted, burned, flooded, and doors damaged.

Building 119
Personnel bunker: Storing liquid scintillation counter, and supporting chemicals. Also contained 0.5-dia x-1-m furnace (photo references DSCO 1557 and DSCO 1554–1563).

Building 167
Computer-processing center, programs, support systems. No equipment, computer media (exploited), Open-source literature on rail gun.

Side Building (167/1)
Room 1 and 2: Nondestructive test center, X-ray, Dye Penetrant, and Magaflux penetrant.

Room 3: Former photography development laboratory at the rear.

Photo references for above DSCO 1534 – DSCO 1538. Significant quantity of documents collected in DOCEX of 11 November 2003.

Building 181
Functionality does not match given description. Building was fitted as a branch of the Al Rashid bank (letter heads). Years of branch records going back to 1998.

Team Bravo Results/Comments

Building 7
Training building.

Rooms 1–31: Recovered electronic media. Documents relevant to keyword list were taken for exploitation. Some rooms had been systematically burned; evidence of destruction of large quantity of

documents. Significant numbers of folders were seen containing receipts for correspondence. Many ledger books, duty rosters. Nothing relevant to ISG identified at this time.

Building 3
Medical reception/health physics.

Room 24: Cryostat examined, cryostat serial number 2130, type CPVDS 30 – 20190 photo reference DSCN 0437. Protective clothing and decontaminant aerosol seen.

Rooms 1 – 30: Documents taken for exploitation from rooms 3, 17, and 30.

Building 82
Electronic Design Center. Computer media and a box of documents collected for future exploitation. Extensive fire damage on first floor; cylinder identified—possible missile transportation canister. Photographs DSCN 0449 and DSCN 0450.

Building 60
Pharmaceutical medical kit and Diagnostic Center. Computer media recovered throughout the building, no documents taken for triage. Burst plasma bags and other items consistent with building function. Chemicals on the floor.

Building 42/43
Technical library and conference facility. Extensive range of Ph.D. theses located in basement and first floor. Building contained in basement a publication production and photographic capability. One box of documents retrieved and a substantial quantity of electronic media, including floppy disk, VHS media, tape cassettes, and photographic negatives recovered from basement, for exploitation.

Iraqi Document Collection:

At 1225 on 22 November, Team Bravo noticed 15 Iraqis removing documents and boxes from building 82. Team Bravo challenged the Iraqis, and their linguist screened the documents and determined then to be professional and scientific publications that were being moved to another building within Tuwaitha for protection. Dr. Saleh Ahmed Hassan was leading this effort for MOST. Building 82 had previously been exploited and cleared by Team Bravo. At the request of the lead SME, Team Bravo also obtained the names of all the Iraqis and the name of the person to whom they reported in MOST.

Team Charlie Results/Comments

Connex Adjacent to Building 182
Contained 2 British Aircraft Corporation infrared laser systems and other related items. Some documents taken for exploitation.

Building 54
Contained growth media, corn meal, agar, and date syrup. Provided access to Building 171 UGF. This building (54) and underground complex (171) were the subject of CBIST survey. UN-labeled bioreactors (4) were identified (Annex E) and a quantity of mission-relevant documents taken for exploitation.

Building 103
Underground water tank, no large exposed entrances. NSTR without diving capability.

Building 75
Environmental radiation monitoring. Some mission-relevant documents taken for exploitation.

Building 56
Biological Fertilizer Plant/Quality-Control Laboratory. Blueprint of facility found, building in accordance with that document. Equipment list found, most of equipment missing. Some mission-relevant documents taken for exploitation.

Building 8
Administration building, quantity of documents taken for exploitation.

Team Delta Results/Comments

Building 12
Divided through middle referred to as 12/1 and 12/2. Visit was carried out with security team in attendance, as this building was identified as a CAUTION.

12/1: Neutron generator building. Offices upstairs; e.g,. health physics, radioisotope study, and flash X-ray.

Ground floor contained:

Rooms 2 and 4: Dr. Jobori, head of neutron source projects office. Office contained documents pertaining to beryllium (Be) and other neutron generators. (Physics was relevant to neutron initiator for a WMD).

Room 7: Contained neutron generator in pristine condition, covered with PVC drapes. Also glove box with U / Pu source.

Room 12: Chemical laboratory containing various acids and a cerium (Ce) source embedded in the floor.

12/2: Sign on outside labeling as Chemical Directorate. Rooms found relating to PCB development, film laboratory, cryogenics; single office had documents relating to laser research.

Room 4: Bottle of Fomblin oil found, used for lubrication of centrifuge bearings, not big enough for a complete centrifuge enrichment farm but could be relevant to laboratory-scale facility.

Room 5: Medical room, contained documents relating to various pathogens documents removed for exploitation.

Room 6: Contained folders and binders of records for pharmaceutical equipment purchase/procurement. Sample taken for exploitation.

Building 10
Cryogenics production. Generators for nitrogen (N_2) and helium (He) seen, not significant in themselves.

Building 43
Auditorium facility NSTR.

During an interview with a source, there were indications of the presence of a large quantity of hidden documents in the basement of this facility. On inspection by members of ISG's Nuclear team in July 2003, it was found that the document store had been systematically burned.

Building 5
Contained offices of IAEC.

Ground floor, mostly burned, could have started in small conference room. Magnetic media taken but no exploitable documents recovered.

Room 37 basement: Document storage for IAEC. Documents found from 2002 dealing with UNSCOM and IAEA inspections; documents gathered and submitted for exploitation.

Building 4
Document storage and reactor operations building, also contained a heating, ventilation and air-conditioning (HVAC) system.

Room 4: Interesting find made of a document referencing "heavy water." This document was among other documents dealing with water for HVAC applications. Specific checks on translation are being made to clarify this reference in view of its possible relevance to a WMD program.

Room 41: Electronics repair office, document found relating to thyristors; document taken for exploitation. Thyristors are relevant to nuclear device trigger systems.

Team Golf Results/Comments

Team Golf, the fifth team, was responsible for visiting all the target structures outside the berms in zones Foxtrot, Golf, and Hotel. During the 3 days of the mission, the team visited 69 structures some not previously identified, confirming MGRS, where possible functionality, and ISG status relevance. With one

exception, Building 151, all the sites were clear, some were destroyed or vandalized, some were the remains of air defense sites, and others were watch towers. A number were inhabited by squatters.

Building 134
May have been an old guard building. Building was wrecked, but among the rubble was found the remains of a water distillation set and steam generation equipment, parts of a laboratory cold chamber, the cabinet of an environmental chamber, and the remains of a centrifuge capable of more than 10,000 rpm.

Annex C
Analysis of the Videotapes Compiled
From Video Recce Mission
5/6 November 2003

Team Delta	**Tape 1**		
Tape Reference	**MGRS/ Room Number**	**Object**	**Comment**
01:39:19	MB 55551 74359	Rubbish dump, with discarded scientific equipment including Andersen samplers and 3-channel analyzer.	Exploit
08:42:16	MB 55512 74351	Collection of documents. Collected on 11 November 2003.	Exploit
09:34:01	MB55520 74367	Biological files and documents. Collected on 11 November 2003	Exploit
11:31:00	MB 55653 74336	Unconfirmed Russian smoke generators?	
14:55:00	MB 55545 74016	ISO container, fertilizer and laboratory equipment. Environmental cabinet by Horaius, imported by Kharl Khob.	
16:40:00	MB 55510 74181	Camera Tower	
17:57:00	MB 55457 74006	With exception of Fire Station at this location associated block at the end of the FS and some temporary buildings containing FS stores, all other buildings at complex of Building 151 have been destroyed and are clear. NFA no further action required.	NFA
19:10:07	MB 55371 73980	Ruined barrack buildings vicinity of 151, no equipment. Connect with steps, which lead to top of berm. AA positions.	
20:39:20	MB 55467 73920	Expended shell cases burned in a dump, adjacent water tank, and Fire station across road. Some other stores buildings at back of complex. Room containing files and neatly arranged records.	Should briefly look at these with a linguist
30:21:00	MB 55608 73719	Camera Tower	
31:08:15	MB 55460 73419	Camera Tower	
32:14:04	MB 55429 73420	Bomb crater, estimated 2,000 lbs Israeli.	
33:05:15	MB 55438 73358	Bomb crater	
33:45:00	MB 55395 73326	Remains of Building 140, no building remains.	Bldg 140 destroyed.
35:40:00	MB 55358 73208	Manhole and cable run, down about 6 feet.	

Team Delta	**Tape 1 (continued)**		
36:28:08	MB 55299 73129	Electricity pylon, surrounded by scrap metal and shelving adjacent to site of Building 140.	
37:26:00	MB 55247 73070	Metal and building rubble. Junk removed from Tuwaitha bombed building in 1991.	
38:10:00	MB 55010 73054	More piles of junk building rubble.	
39:04:28	MB 54760 73099	Bomb crater, another 2000, explosion caused pinnacle in the middle.	
39:38:03	MB 54728 73132	Camera Tower, identifies boxes in junk yard.	
40:35:00	MB 54865 73413	Number of ruined probable guard shacks.	
41:35:00	MB 54868 73453	Ruined guard shack. Barrack garden.	
42:40:00	MB 55155 73566	Full face respirator. Symbol bent minaret at Mosel indicating G Bin Hyer. Two or three symbol of local manufacture in Mosel.	
Team Delta	**Tape 2**		
Tape Reference	**MGRS**	**Object**	**Comment**
00:52:13	MB 54380 73136	Camera Tower	
02:27:29	MB 54272 73283	Possible Smoke Canisters	
03:09:27	MB 54163 73483	Camera Tower	
03:48:01	MB 53981 73832	Camera Tower	
05:02:06	MB 53949 73892	Unknown Structure	
06:44:00	MB 53801 74180	Camera Tower	
08:06:29	MB 53938 74363	Camera Tower	
08:50:00	MB 54233 74636	Camera Tower	
10:25:21	MB 54301 74931	Possible concrete tanks.	

Team Delta	**Tape 2 (continued)**		
11:39:24	MB 54476 74866	Camera Tower	
13:07:14	MB 54522 74793	Cluster of buildings in area of Building 115. Collected 11 November 2003.	Exploit
17:06:12	MB 54527 74770	Unused filter system and documents in cluster of buildings in area of Building 115. Collected 11 November 2003.	Exploit
17:17:58	MB 54503 7465?	Adjacent to health center (inside perimeter). Side road blocked with wrecked bus	
18:33:02	MB 54695 74838	First of a cluster of buildings at Building 90 complex.	
20:27:21	MB 54685 74889	Outbuildings at building 90 complex showing manhole cover and high-capacity rectifiers and document.	Exploit
22:00:22	MB 54679 74916	Part of substation complex, showing digging for looters to steal copper cables.	
23:04:07	MB 54692 74925	Substation control room, showing "vynconstruct" equipment. Shot of looters digging to steal cable and water system. Shot of room behind control room and more cable looting.	
28:52:09	MB 54720 74893	Large building at substation, small entrance and large swimming pool type tanks at each end (20 x 6 x 5 deep meters). Sill at Building 90 complex.	
32:28:15	MB 54732 74891	Entry to main building at Building 90 complex. Large hole going down. Evidence of laser, optical, and possible rail gun research. Some documents recovered for CMPC, some video-ed. Shot of jar containing Strontium compound.	Exploit. Nuclear and Chemical.
Team Delta	**Tape 3**		
Tape Reference	**MGRS**	**Object**	**Comment**
	MB	Video of rooms in 90 complex main building. Photon optical bench Cambridge UK. Photos of laser impact on targets. Faraday cage (large).	
25:07:25 31:46:24	MB 54799 74841	Electrical control equipment presumed to have come from main building in 90 complex. Another part of Alcatel equipment, presumed from main building in 90 complex and possibly linked with previous Alcatel device. Presumed important as the equipment was sandbagged for protection. Jobin Yvon equipment looks expensive. Expensive looking new Australian equipment in a wooden case, GBC Scientific Equipment, 12 Monterey Road, Dandenong, Victoria 3175 Australia. Passed QA, 29 Oct 2002. Serial Number E1183, passed by "Marg." GBC Integra, XL, shipped to Medical Scientific Corporation.	Optical spectrometer.

Team Delta	**Tape 4 (continued)**		
33:10:06	MB 54823 74912	Entered building as continuing part of 90 complex with autoclave (large) and incubator/shaker with UNSCOM label B002236.	
43:15:15	MB54013 74969	Oil fired boiler used for steam generation to power autoclave.	
44:42:24	MB 54840 75003	Camera Tower	
46:14:06	MB 54820 75017	Small building at rear of 90 complex with equipment junk inside. Adjacent container with more junk and an object, which looked like part of HT equipment.	More detailed examination
51:35:17	MB 55150 74914	Camera Tower	
52:33:27	MB 55268 74721	New building not yet completed.	
	Not readable	New building not yet completed.	
56:24:19	MB 55293 74244	Wrecked buildings on top of berm.	
Team Delta	**Tape 4**		
Tape Reference	**MGRS**	**Object**	**Comment**
02:56:15	MB 55270 73636	View from berms over Tuwaitha complex.	
05:08:28	MB 54962 73609	View from berms over Tuwaitha complex.	
01:25:15	MB 54418 73191	View from berms over Tuwaitha complex.	
03:03:18	MB 54167 73724	View from berms over Tuwaitha complex.	
07:44:14	MB 55975 75412	Area H Trashed Workshop area.	
11:06:05	MB 55949 75488	Area H Trashed Workshop area.	
13:33:29	MB 56070 75324	Area H Trashed Workshop area.	

Team Alpha	**Tape 5**		
Tape Reference	**MGRS/ Room Number**	**Object**	**Comment**
00:33:19	MB 54832 74042	Building 189, underground bunker with surrounded by damage. Entrance located on top and descends into the bunker.	System empty NFA.
02:21:08	MB 54839 74060	Building 188, underground emplacement with entrance at the top. UGF completely empty.	NFA.
03:44:13	MB 54816 74043	Water Tower. (No particular building number)	NFA
04:09:08	Not provided	Evaporative Cooling Tower	NFA
04:45:29	MB 54789 74039	Underground structures 190 and 191. Steps going down, not explored.	Better look?(NFA)
05:42:15 08:37:13 09:50:00 15:45:00 17:40:40 21:20:00 26:36:00 29:30:00 39:30:00 42: 46:40:00 48:20:00 51:30 52:13 57:22	MB 54875 74024 1021 1023 1023, 1025 1030, 60, 1003 !, 4, 5, 2018 2006, 2002, 2005 1001, 3rd LHS. Glove box 1007 Laser Laboratory	 Building 12, large brick, two-story structure. Note windows on the bottom floor are barred. Extensive looting throughout with rooms randomly containing what remains of original equipment, chemical containers and chemical waste storage, evidence of film-processing operation, electrical power equipment and devices, work tables and work stations, laboratory glassware, some office furniture, notebooks, binders and files strewn about, and debris. At least, room was designated as a Spectroscopes Laboratory. The south end of Building 12 contained new areas under construction, which contained nothing. Section of Building 12 adjacent to new construction contained much of the same as primary building area. Southwest end of Building 12 contained vacant rooms with new construction, probably never occupied. 44:00:00 Hazard symbol on door. Grey building to south of Building 12. 49:00:00 remote manipulator and room with PVC.	 Some exploitation required. Room 5, 2018 No exploit. 2001, 2002, 2004 1001, laser laboratory
Team Alpha	**Tape 6**		
Tape Reference	**MGRS / Room Number**	**Object**	**Comment**
00:00:13		Complex of buildings number 167	
00:25:11	55010 74429	Two-story brick structure, northernmost building	
01:15:00		Room 4	Exploit

Team Alpha	**Tape 6 (continued)**		
03:18:00		Room 3	Exploit
05:10:00		Room 11	Exploit
		Room 9	
07:10:00		Room 7 Upstairs binders	Exploit
07:14:00		Room 14 computer media	Exploit
08:00:00		Room 15 / 16 Design of Information systems	Exploit
09:25:00		Room 17	
10:00:00		Room 18 computer media	Exploit
		Room 19	
11:59:00		Room 20 Computer/Maths techniques	Exploit
13:06:00		Room Technical manuals IMB token ring map of Tuwaitha taken back.	Exploit
14:25:00		Eastern building of Complex	Exploit
15:00:00		Western Admin Block piled high with documents.	Exploit
17:35:00		Documents	Exploit
18:20:00		Rabbit warren of offices	Exploit
21:00:00		Agricultural program	
21:20:00		Blueprints.	
26:00:00		Papers and ledger	
26:15:00		Document storage area	Exploit
30:00:00		Last building of 167 Complex	
30:29:00		Pieces of paper on the floor, torn up.	Exploit
32:30:00		Organizational chart	
33:42:00		Ledgers on bookcase.	Exploit
35:35:00	54794 73862	Connex Container large, end of road in section E, underground storage/ Building 192 / 76	Exploit
36:50:01	54605 73502	Boiler House	NFA
38:38:19	54527 73391	Building 72 Transformer station. Electrolyte production of H_2	NFA

Team Alpha	**Tape 7**		
Tape Reference	**MGRS / Room Number**	**Object**	**Comment**
00:10:00		Area 41? 1015, 1016 & 1017.	
01:21:115	54870 73969	Group of structures number 38.	Exploit
01:45:16	54942 73935		
02:14:00		Equipment outside.	
04:10:00	54951 73928		
04:45:00		Building 37 Storage Containers. Welded shut.	Exploit
05:05:00		Storage containers 9 feet long.	
06:00:00	54917 73896	Connex Container with soil blocking each end	Open/Exploit
	54930 73770	Building 40, 800 mRem/Hour. Do not enter radiation.	NFA
07:17:15		Correction to count rate. 800–1,000 cpm	
07:35:00	54999 73833	Underground facility Building 200. Radioactive source at far end. 800–1,000 cpm Gamma.	
08:53:00	55018 73846	Building 31 Water-cooling tower. Building destroyed.	NFA
09:30:00	55228 73797	196 underground facility personnel bunker.	NFA
10:16:10	55229 73780	Building 30, completely destroyed.	NFA
10:41	55229 73734	Building 19, completely destroyed.	NFA
11:00:00	55341 73770	Structure 170.	NFA
11:37:20	55099 73809	Building 32 storage buildings.	NFA
12:10:00	55239 74060	Building 168, small, with two rooms. Water filtration system, second room empty.	NFA
Team Beta	**Tape 8**		
Tape Reference	**MGRS / Room Number**	**Object**	**Comment**
00:00:00	54676 73819	Building 65 & 66 used to be one large building, behind is another building not on map, at end of 65.	NFA
01:11:25	54657 73866	Storage Tank writing on blackboard. Building 64	Linguist
01:35:17	54656 73867	Building 64 Storage Tank writing on blackboard.	Linguist

Team Beta	**Tape 9**		
Tape Reference	**MGRS / Room Number**	**Object**	**Comment**
00:05:00	54931 74297	Building 118 UGF	NFA
03:40:08	54750 74166	Building 187	NFA
06:35:23	54692 74122	Building 14	NFA
08:57:25	54692 74189	Building 186 UGF Entrance blocked	NFA
12:42:27	54661 74215	Bldg 184	NFA
15:31:28	54637 74283	Bldg not on map entrance. Above ground bunker 54639 74288, 54649 74286, 54638 74277, 54631 74286	NFA
18:00:00	54639 74289	Liquid Scintillation analyzer 1600CA Tri-Carb	
18:13:11	54638 74288	North East Corner	
18:34:28	54649 74286	Corner 2	
18:56:26	54638 74276	Corner 3	
19:40:00	54631 74287	Corner 4	
20:08:25	54795 74562	Bldg 194 is in fact not a UGF but is a huge water tank flowing approx 3 m deep.	NFA
22:21:19	54815 74498	Bldg 195 Cylindrical Tank.	NFA
24:02:21	54638 74488	Bldg 171, both entry doors were locked but opened	Exploit
30:19:08	54516 73642	Building 76	NFA
33:16:12	54530 73571	Building 71	NFA
36:11:01	54463 73590	Building 75	Exploit
37:00:00	75/1	Floppy disks some documents	Exploit
38:50:00	75/2	Floppy disks some documents	Exploit
39:50:00	75/3	Blueprint of building	Exploit
41:42:00	75/4	Lead bricks, protecting source? And Filters?	D & E
42:15:00	75/5	Empty room.	
45:41:06	75/9	Few documents.	Exploit
46:45:19	75/11	Few documents.	Exploit
47:41:28	75/12	Few documents.	
48:31:00	75/13		
48:54:00	75/14		
49:15:13	75/16	Upstairs, some documents, box of floppy disks.	Exploit

Team Beta	**Tape 10**		
Tape Reference	**MGRS / Room Number**	**Object**	**Comment**
00:04:06	55201 73986	UGF Building 197, radiation from wall crack.	Empty, NFA
02:04:14	55247 73892	Building 198, building empty.	Empty, NFA
03:25:26	55118 73792	Building 32 Second Part, 4 trailers side by side	Empty, NFA
Team Beta	**Tape 11**		
Tape Reference	**MGRS / Room Number**	**Object**	**Comment**
00:00:00	54810 74115	Building 13	
01:00:12	13/1	Some documents.	Exploit.
01:28:03		Device on desk ?	?
01:40:00		Some documents. SAER device.	Exploit.
02:29:12	13/4	Few papers.	Exploit.
03:16:07	13/5	Few papers. Personnel File, photo and disk.	Exploit.
04:20:00		Steam generator–hot air . Ets LEQUEUX sa	
04:45:04	13/6		
05:25:00	13/7		
05:54:00		Contamination Danger Notice. Drum of Ethanol. Lead bricks.	Visit.
06:40:00	13/8		
09:00:28	13/9		
09:56:00		Barrel of Acetone.	
10:46:00	13/10	Stairs down to basement of Building 13.	
12:40:00	13/11	Drawing Board.	
15:00:00		Heat Exchanger, Stainless Steel Tubing.	
16:00:00	13/13	Mono Chloro Di Floro Methane container (Freon).	
17:00:00	O/S 13	X-Ray Fluorescence Spectrometer. VF-320 Shimadzu	
18:05:00	13/14		
19:42:00	13/16		

Team Beta	Tape 11 (continued)		
20:30:00	13/17		
21:00:00	13/18		
21:33:00	13/19		
22:00:00	13/20	Oven/kiln, notebook.	
23:25:00	13/21		
24:47	Stairs	To roof of 13.	
26:00:00		Access to rest of building denied.	
30:06:00	Stairs	Pile of lead bricks.	
31:50	Room 7 & 8		
00:05:00	55118 73959	Building 24	
01:45:00	24/1 upstairs	Room piled full of equipment spares.	
03:55:00	24/2	Some ledgers and notebooks.	Exploit
04:47:00	24/3	Quantity of documents on bookshelf	Exploit
05:43:00		OSIRIS Certificate.	Exploit
06:00:00	24/4	Documents	Exploit
06:30:00	24/5	Documents	Exploit
07:08:00		Manufacturing Plant for X-ray Sonar High Speed Centrifuge	Exploit
07:23:00	24/6	Documents	Exploit
08:25:00	24/7	More documents and laboratory notebooks.	Exploit
09:19:00	24/8	Documents	Exploit
10:25:00	24/9	Documents	Exploit
11:07:00	24/10	Documents	Exploit
11:33:00	24/11	Documents	Exploit
12:25:0	24/12	Empty	
13:00:00	24/13		
13:44:17	24/14	Quantity of Documents on floor and book case.	Exploit
14:17:00	24/14	Closeup of bookcase and ledgers.	Exploit
15:18:00	24/15		
16:00:00	24/16		
16:39:00	24/17	No outside door to latter. Few documents	

Team Beta	**Tape 11 (continued)**		
17:31:00		High Voltage Trigger Type US-4	
17:50:00		Farnell Stabilized Power Supply	
17:59:00	24/18		
19:30:00		Exit building.	
Team Charlie	**Tape 12**		
Tape Reference	**MGRS / Room Number**	**Object**	**Comment**
00:00:00	55055 74134	Building 7	
00:34:00		SE entry, documents	Exploit
00:40:00	7/1	Documents	Exploit
00:45:00	7/2	Burned out	
00:50:00	7/3	Burned out	
00:58:00	7/4	Documents	Exploit
01:10:00	7/5	Documents and ledgers in bookshelf.	Exploit
01:23:00	7/6	Safe, some papers on the floor.	Exploit
01:25:00	7/7	Documents and ledgers in bookshelf, large quantity.	Exploit
01:50:00	7/8	Safes and documents on floor.	
02:14:00	7/9	Papers on the floor.	Exploit
02:18:00	7/10	Some papers on the floor, binders in bookshelf	Exploit
02:43:00	7/11	Papers on floor.	Exploit
02:46:00	7/12	No documents.	
	7/13	Bathroom.	
02:54:00	7/14	Some papers. En suite facility.	Exploit
03:28:18	7/15	Some papers.	Exploit
03:40:00	7/16		
03:48:00	7/17	Some papers.	Exploit
0404:07	7/18	Papers.	Exploit
04:13:00	7/19	Some ledgers under desk.	Exploit

Team Charlie	**Tape 12 (continued)**		
04:30:00	7/20	Papers on floor, ledgers in bookshelf.	Exploit
04:58:00	7/21	Ledgers and papers on floor.	Exploit
05:07:00	7/22	Documents on floor.	Exploit
05:15:08	7/23	Large bookshelf full of ledgers.	Exploit
05:28:00	7/24	Some ledgers behind desk.	Exploit
05:35:00	7/25	Papers on floor.	Exploit
05:48:00	7/26, 27, 28, 29, 30	Staircase, bathroom and burned offices, ash from papers.	Anything readable?
06:36:00	7/31	Some papers on floor.	Exploit
	7/32 & 33	Restrooms.	
06:50:00		View of burned corridor, facing West.	
07:00:00		One room upstairs, building services and views of roof.	
07:22:24	55096 74081	Building 8	
07:53:03	8/8	First room on the left, papers in entrance hall.	
08:23:11	8/6	Papers on floor.	Exploit
08:55:28	First room	On LHS following Security Barrier, papers.	Exploit
09:03:00	Second	Papers on floor.	
09:07:00	Third	Papers on floor, plus filing cabinet with documents.	Exploit
09:17:00	Fourth	Papers on floor.	Exploit
09:24:07	Fifth	Papers on floor	Exploit
09:36:00	Sixth	Papers on floor.	Exploit
09:44:00	Seventh	Papers on floor.	Exploit
09:50:00	Restrooms		
09:56:00		West end of security area.	
10:16:24		Papers on floor exploit.	Exploit
10:20:00		Last room on LHS, papers on floor, en suite facility. Storage nook full of ledgers.	Exploit
10:44:00		North side of hall way east end of Building 8.	Exploit
11:13:21		Some papers.	Exploit
11:20:03		Some papers on floor.	Exploit
11:28:11		Some papers on floor.	Exploit

Team Charlie	Tape 12 (continued)		
11:40:05		Large quantity of documents on floor.	Exploit
11:57:00	Next room	Quantity of documents on floor.	Exploit
12:06:02		Filing cabinet with ledgers and documents on floor.	Exploit
12:15:23		Wrecked copier, documents on floor.	Exploit
12:36:08	5	First left after security barrier. Few documents.	Exploit
12:43:04	4	Papers on floor.	Exploit
12:49:00	3	Junk no papers.	
12:58:28	2	Few papers.	Exploit
13:10:17	Next on LHS	Some papers.	Exploit
13:28:21	Last room	Documents.	Exploit
13:40:00	Stairs up to roof	Door to utility area housed in small room on roof.	
14:25:00	55024 74046	Building 181 Door on north side, all doors and windows were fitted with additional security bars.	
15:13:00	1st on LHS	Papers on floor. Cubicles, papers in back room.	Exploit
16:05:00	2nd	Papers on floor. Filing cabinet full of documents. Large quantity of documents in small room.	Exploit
17:00:00		Views of safes, broken open and empty.	
17:25:00		Building 11, exterior shot of building and associated shed and transmission tower.	NFA
17:40:00		Small building south of Bldg 11, no papers.	NFA
17:57:00	54887 74001	Building 11. Occupied by Security Guards.	NFA
18:41:25		Room off room , some documents, blocked in.	Exploit
18:50:00		Found AK47, called for advice.	
20:00:00	Office / Sub-station	Few documents	Exploit
20:35:26	Diagram	Substation switching system.	
21:00:00		North side of Building 11.	
21:10:00		Missing East end of Building 11.	
22:00:00	Stairs	Leading to small storage room, with racking, no documents.	
22:27:00		Exterior shots of Building 10.	
22:41:11	54918 74045	MGRS of Building 10 and entry wing. Some documents.	Exploit

Team Charlie	**Tape 12 (continued)**		
23:00:00		Cryogenic equipment.	
25:44:11		Shot of Unit 25, liquid N2 generator.	
26:10:00		Small office, some documents.	Exploit
26:25:00		Danger Toxic sign.	
27:05:00		Shot of some instructions relating to equipment.	
27:31:28		Restrooms and Room with storage of equipment.	
27:40:00		Liquid helium equipment.	
28:06:12		Shot of BOC TurBOCool helium Liquifier.	
28:29:22		Building 24 adjacent to OSIRAC bombed by Israeli's	
28:53:13	55115 73961	Building 24 MGRS, followed by shots of entrance and foyer.	
	24/1	Odd papers on floor	Exploit?
29:49:21		Management notice in Arabic.	Translate
		Few binders on desks and floor of rooms viewed.	Exploit
30:34:15	24/8	No documents.	
30:50:00	24/9	Few documents.	
31:22:00	1st of east end.	Binders on floor.	Exploit
31:33:00	2nd	Some drawings.	Exploit
31:48:00		Drawing of Central Workshop by Bilcon Projects, Ltd., England 0226 71262.	
32:00:00		Drawings of administration building.	Exploit
32:25:00	24/25	No papers.	
33:00:00	Un-num rooms	Some binders, Arabic notes on drafting table.	Exploit
33:25:00		Restrooms, followed by stairs leading down.	
33:55:00		Archive of documents Vast quantity.	Exploit
34:15:11		Basement facing east. Numbered pumps, electrical services and HVAC system.	
35:41:00		Subbasement, 40 m long, flooded to 2 feet.	Further examination?
36:38:00		Blocked off end of building, bomb damage, not entered.	
37:20:00		Small building to east of 24, serious damage.	
37:31:12	55150 73916	MGRS of little building behind 24. Serious bomb damage.	NFA

Team Charlie	Tape 12 (continued)		
37:44:00		Elevator shaft into subbasement.	
38:14:09		Spiral staircase leading down.	
38:25:00		Shots of destroyed building.	
39:57:00		Buildings 22 and 23.	NFA
40:00:00	55123 73843	MGRS for small Building 23.	
40:35:00		Both parts of Building 22	
41:25:00		Shots of hot cells and remains of manipulators.	
		Shots of bombed out sections of Bldg 22.	
		Building dangerous, no further exploration.	
		Shot of access way between 22 and 23, is this remains of pneumatic rabbit system?	NFA
43:00:00	55231 73853	MGRS of between Buildings 22 and 23.	
44:30:00	55192 73874	Large underground basement. NW corner. Grids of all four corners.	
44:40:00	55221 73892	North East Corner.	NFA
44:56:04	55242 73854	South East Corner.	NFA
45:05:00	55214 73839	South West Corner	NFA
45:10:00	55242 73842	SW corner of building with substation station facility	NFA
45:24:00		Utility/power control or supply building.	
46:41:06		SE corner of building 34.	NFA
49:11:04	Various rooms.	East side of building, high indicated count rate, sacks of Portland cement.	
49:58:09		Bottle of Halon 1301	
50:07:0	55094 73719	Building 34, tin shed full of scrap metal, cable, etc.	

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Annex D
Results of Mission Survey of Tuwaitha Nuclear Complex Over the Period 20-22 November

Results of mission survey of Tuwaitha Nuclear Complex over the period 20-22 November 2003.

Tuwaitha Nuclear Research Center

Building Numbers

BLD_NUMBER	GRID_REF	DMS	MGRS	PERCEIVED FUNCTIONALITY	STATUS	TYPE
0	0	unknown	unknown	unknown	Clear	unknown
1	5574	331222.32N 0443107.76E	38S MB 5518174250	Personnel control office	Clear	BRAVO
2	5574	331220.16N 0443108.98E	38S MB 5510674184	Restaurant	Clear	
3	5574	331225.92N 0443105.88E	38S MB 5510774361	Administrative building	Clear	BRAVO
4	5474	331225.56N 0443059.77E	38S MB 5494874351	Biology/agricultural laboratory and headquarters	Clear	Triaged
5	5474	331221.96N 0443100.48E	38S MB 5496674240	Environmental research laboratory	Clear	DELTA
6	5574	331219.88N 0443101.92E	38S MB 5500374173	Personnel bunker	Questionable	UGF, 5m x 27m; either doesn't exist or can't find entrance, does contain pipes under manholes and cement slabs
7	5574	331218.08N 0443102.64E	38S MB 5502274117	Training office	Clear	Large Task, BRAVO
8	5574	331216.56N 0443103.35E	38S MB 5504074073	External relations department	Clear	Large Task; CHARLIE
9	5474	331217.64N 0443057.96E	38S MB 5490174107	Chemical analyses and radiochemical laboratories	Hazard	
10	5474	331214.76N 0443057.96E	38S MB 5490074018	Chemical analyses laboratory	Clear	Small Task; DELTA
11	5474	331215.48N 0443059.04E	38S MB 5492874040	Telephone communications and power supply	Clear	Small Task; DELTA
12	5474	331214.40N 0443055.79E	38S MB 5484474007	Engineering workshop and neutron generator	Clear	Large Task Caution; DELTA
13	5474	331217.28N 0443054.72E	38S MB 5481774096	Research reactor IRT-5000	Clear	NUC Caution; BRAVO
14	5474	331217.64N 0443049.31E	38S MB 5467774108	Electrical power sub-station	Clear	
15	5474	331220.88N 0443050.40E	38S MB 5470574208	Isotope production laboratory	Clear	DTRA
16	5474	331223.04N 0443055.08E	38S MB 5482774273	Mechanical production workshop for IRT	Clear	
17	5474	331222.32N 0443052.20E	38S MB 5475274252	Mechanical production workshop and water supply	Clear	ALPHA
18	5474	331224.84N 0443055.79E	38S MB 5484674329	Agricultural and biological research laboratories	Clear	Triaged
19	5573	331205.40N 0443111.28E	38S MB 5524473728	Open air pool (Exposed basement)	Destroyed	
20	5573	331206.84N 0443110.56E	38S MB 5522573773	Offices and stores	Destroyed	
21	5573	331206.12N 0443108.76E	38S MB 5517973751	Offices and stores	Destroyed	
22	5573	331209.00N 0443107.31E	38S MB 5514273840	Hot laboratory LAMA	Destroyed	
23	5573	331209.00N 0443111.28E	38S MB 5524473839	Former site of the engineering hall	Destroyed	
24	5573	331211.88N 0443105.88E	38S MB 5510573929	Tamuz-2 zero power reactor	Clear	Large Task NUC; DELTA
25	5573	331214.40N 0443105.52E	38S MB 5509674006	Store	Destroyed	
26	5573	331213.68N 0443104.08E	38S MB 5505973984	Chemical cleaning workshop	Destroyed	
27	5574	331214.40N 0443103.00E	38S MB 5503174006	Caravans	Destroyed	
28	5473	331214.04N 0443101.20E	38S MB 5498473996	Caravans	Destroyed	
29	5573	331212.68N 0443102.64E	38S MB 5502173951	Chemical cleaning workshop and caravan	Destroyed	
30	5473	331212.24N 0443101.92E	38S MB 5500273940	Chemical cleaning workshop	Destroyed	
31	5573	331210.44N 0443103.35E	38S MB 5501873846	Cooling tower for Tamuz	Destroyed	
32	5573	331208.28N 0443105.16E	38S MB 5508673818	Warehouse and Empty Trailers	Clear	
33	5573	331205.40N 0443106.24E	38S MB 5511373729	Offices	Destroyed	
34	5573	331204.68N 0443104.44E	38S MB 5506673707	Offices and stores	Clear	
35	5573	331206.84N 0443103.72E	38S MB 5504873774	Radioactive waste treatment station (RVTS)	Hazard	
36	5573	331209.00N 0443101.92E	38S MB 5500273840	Above ground Earth mounded bunker	Hazard	UGF, Radioactive waste storage, 10.5m 35, was 280 and 36
37	5473	331211.16N 0443100.12E	38S MB 5495673907	Training offices and storage welded shut	Clear	ALPHA
38	5473	331212.24N 0443058.68E	38S MB 5491973940	Training offices and laboratories	Clear	
39	5473	331208.28N 0443100.48E	38S MB 5496473818	Permanent solid waste storage	Hazard	
40	5473	331206.12N 0443058.31E	38S MB 5490873752	Waste storage for IRT	Hazard	
41	5473	331211.88N 0443054.00E	38S MB 5479773930	Nuclear instrument calibration and waste storage	Clear	
42	5474	331233.12N 0443057.68E	38S MB 5489474584	Technical library and conference rooms	Pending	BRAVO
43	5474	331234.56N 0443056.88E	38S MB 5487574628	Technical library and conference rooms	Clear	DELTA
44	5474	331234.92N 0443057.96E	38S MB 5490374639	HVAC for library and conference rooms	Clear	
45	5474	331231.32N 0443054.72E	38S MB 5481974529	Water treatment and pumping facility	Clear	
46	5474	331229.16N 0443055.08E	38S MB 5482874462	Water treatment	Clear	
47	5474	331227.00N 0443054.72E	38S MB 5481874296	Biology, animal housing and agricultural laboratories	Pending	Triaged

Results of mission survey of Tuwaitha Nuclear Complex over the period 20-22 November 2003. (continued)

Tuwaitha Nuclear Research Center

Building Numbers

BLD_NUMBER	GRID_REF	DMS	PERCEIVED FUNCTIONALITY	STATUS	TYPE
46	5471 311223.1kN 0443055.0kE	33S MB 5462874462	Water treatment	Clear	
47	5471 311227.00N 0443054.72E	33S MB 5461874396	Biology animal housing and agricultural laboratories	Pending	Triaged
48	5471 311227.72N 0443054.36E	33S MB 5460974418	Biology and agricultural laboratories	Destroyed	
49	5471 311227.36N 0443052.56E	33S MB 5476274407	Greenhouse and agricultural laboratories	Pending	Triaged
50	5471 311225.56N 0443050.40E	33S MB 5470874352	Laboratory for cereal and crop research, machine repair	Pending	Triaged
51	5471 311228.08N 0443049.3E	33S MB 5467874423	Soil workshops and stores	Clear	ERAVO
52	5471 311227.72N 0443048.60E	33S MB 5468074418	Agricultural and biological laboratory	Pending	Triaged
53	5471 311227.36N 0443047.88E	33S MB 5464174407	Chemical production facility	Clear	ALPHA
54	5471 311229.88N 0443047.1kE	33S MB 5462374485	Lightning arrestor, UG storage, and AG/BIO lab	Clear	Pending for Bio Team; CHARLIE Clear
55	5471 311230.24N 0443045.36E	33S MB 5457674496	Animal housing	Pending	Triaged; Cleared by MAJ Accardi
56	5471 311229.52N 0443043.92E	33S MB 5457974471	Microbiological laboratory	Clear	CHARLIE
57	5471 311227.00N 0443045.00E	33S MB 5458674397	Environmental research department laboratory	Clear	Under construction
58	5471 311228.80N 0443042.84E	33S MB 5458774452	Laundary	Clear	
59	5471 311224.84N 0443047.1kE	33S MB 5462274330	Health physics building	Clear	Triaged; ALPHA
60	5471 311221.68N 0443034.5kE	33S MB 5429574232	Pharmaceutical/medical kit and diagnostic production	Clear	Triaged; BRAVO
61	5471 311218.36N 0443039.6kE	33S MB 5442574131	Incinerator	Clear	
62	5471 311218.92N 0443039.94E	33S MB 5443574097	Sewage station	Clear	
63	5471 311214.48N 0443039.24E	33S MB 5445874009	Cold material testing laboratories	Clear	DELTA
64	5471 311210.08N 0443048.24E	33S MB 5464873975	Radiological waste process building	Clear	Required Task per Accardi; no does
65	5470 311207.56N 0443048.96E	33S MB 5466877798	Liquid chemical waste treatment	Destroyed	
66	5470 311208.28N 0443047.52E	33S MB 5462973820	Offices and training building	Destroyed	
67	5470 311205.40N 0443045.72E	33S MB 5458273731	Deionized water production units	Hazard	
68	5470 311153.52N 0443046.08E	33S MB 5458073365	Utilities and storage	Destroyed	Triaged
69	5470 311157.84N 0443047.8E	33S MB 5461873498	Oil storage	Destroyed	Triaged
70	5470 311157.48N 0443045.72E	33S MB 5458173487	Electrolytical production of hydrogen	Destroyed	Triaged
71	5470 311200.00N 0443043.56E	33S MB 5452573565	Transformer sub-station	Destroyed	
72	5470 311154.24N 0443043.28E	33S MB 5455773388	Transformer sub-station	Clear	
73	5470 311155.32N 0443041.72E	33S MB 5447873421	Workshop for fuel fabrication and material testing	Destroyed	
74	5470 311159.28N 0443039.84E	33S MB 5446373590	Electrical power sub-station	Destroyed	
75	5470 311200.72N 0443040.32E	33S MB 5441173588	Building with substantial laboratory	Clear	CHARLIE
76	5470 311202.1kN 0443042.84E	33S MB 5450773632	Canteen	Clear	
77	5470 311210.88N 0443036.3kE	33S MB 5434073894	Utilities workshop	Clear	MAJ Accardi: either heavily looted or never finished
78	5470 311210.08N 0443035.27E	33S MB 5432773877	Utilities workshop	Clear	MAJ Accardi: either heavily looted or never finished
79	5470 311208.64N 0443032.04E	33S MB 5422873833	Physics laboratory	Clear	MAJ Accardi: Does not exist
80	5470 311211.52N 0443032.04E	33S MB 5422973922	Nuclear physics laboratories	Destroyed	
81	5471 311215.48N 0443034.2E	33S MB 5426574043	Screw worm research and medical laboratory	Clear	Triaged; CHARLIE
82	5471 311220.1kN 0443030.96E	33S MB 5420274188	Electronic design department	Clear	ERAVO
83	5471 311218.72N 0443028.68E	33S MB 5417474143	Utilities	Clear	
84	5371 311218.36N 0443023.76E	33S MB 5405674133	Chemistry and chemical engineering research	Destroyed	
85	5471 311219.44N 0443023.44E	33S MB 5408674168	Chemical research laboratories	Destroyed	
86	5471 311222.04N 0443019.80E	33S MB 5442774553	Engineering design and mapping center	Clear	ERAVO
87	5471 311232.40N 0443043.20E	33S MB 5452174563	Medical center	Clear	MAJ Accardi
88	5471 311233.84N 0443041.76E	33S MB 5446974609	Recreation center and officers club	Clear	
89	5471 311236.00N 0443043.56E	33S MB 5453074671	Caravans	Destroyed	
90	5471 311243.56N 0443051.84E	33S MB 5474674905	Physics building and laser center	Clear	GOLF
91	5672 311110.56N 0443201.68E	33S MB 5654172128	Site C, Baghdad gelbowcake storage area	Hazard	
92	5773 311154.68N 0443258.92E	33S MB 5802973383	Military facility	N/A	
93	5772 311118.24N 0443225.08E	33S MB 5774872267	SA-2 Military facility	Clear	Griffin during recce
94	5372 311125.44N 0443019.80E	33S MB 5361272505	Military facility	N/A	

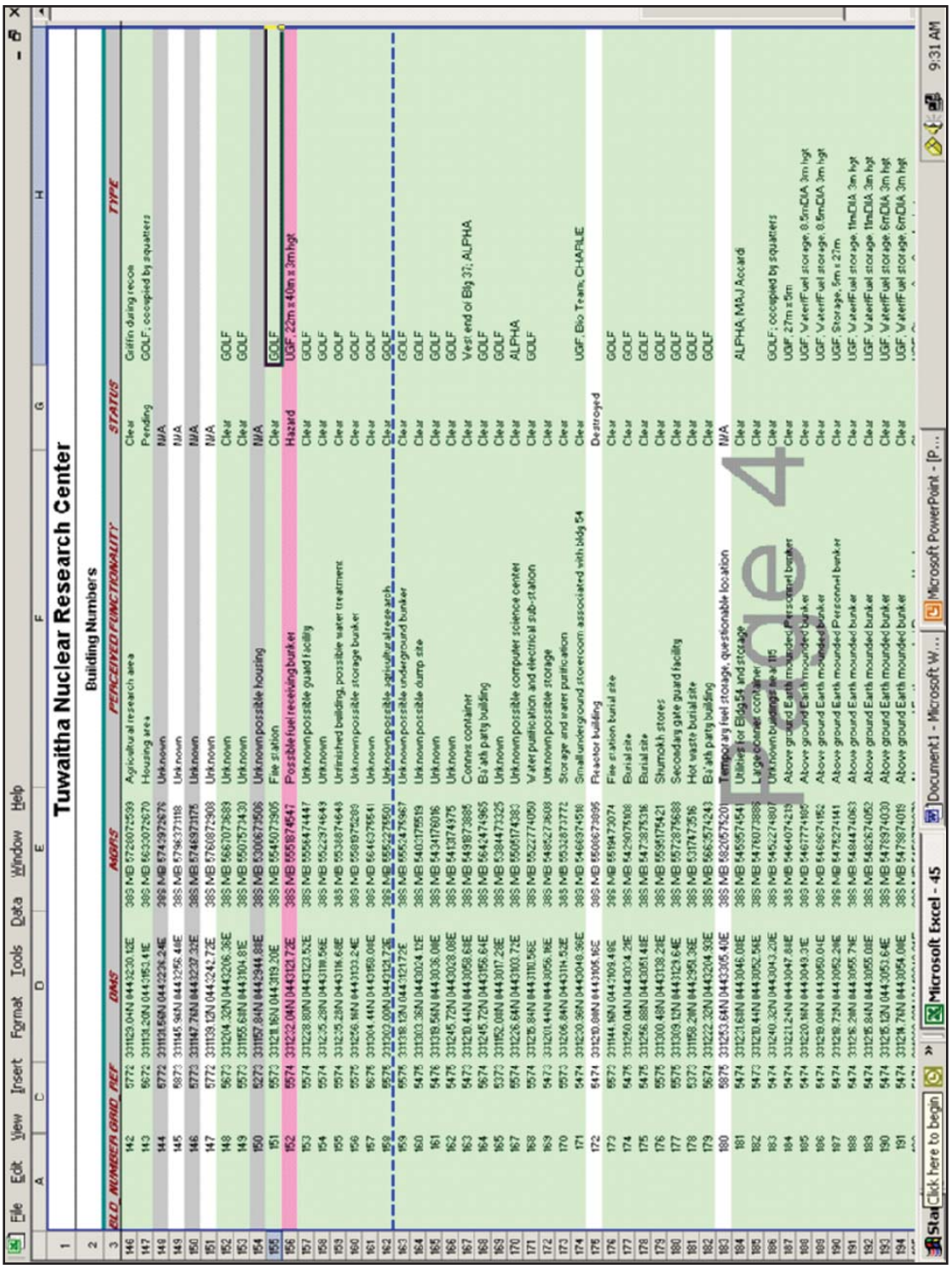
Results of mission survey of Tuwaitha Nuclear Complex over the period 20-22 November 2003. (continued)

Tuwaitha Nuclear Research Center

Building Numbers

BLD_NUMBER	A GRID_REF	DMS	MGRS	PERCEIVED FUNCTIONALITY	STATUS	TYPE
94	5372	331125.44N 0443009.80E	38S MB 5367272505	Military facility	N/A	
95	5678	331038.48N 0443214.28E	38S MB 5688575972	Ash-Shaykhali military storage facility	N/A	
96	5278	331249.32N 0442939.16E	38S MB 5268475092	Military facility	N/A	
97	5672	331134.44N 0443144.04E	38S MB 5608872771	Military facility	Clear	GOLF
98	5475	331301.28N 0443105.88E	38S MB 5511275447	Military facility	Clear	GOLF
99	5572	331116.08N 0443009.12E	38S MB 5518872210	Military facility	Clear	GOLF
100	5675	331253.64N 0443214.40E	38S MB 5680775207	Military facility	Clear	GOLF
101	5574	331227.00N 0443142.96E	38S MB 5606774390	Military facility	Clear	GOLF
102	5475	331251.48N 0443040.64E	38S MB 5445875151	Military facility	Clear	GOLF
103	5474	331223.48N 0443055.08E	38S MB 5482874595	Underground water tank	Clear	(Pump out?) ways 193 and 194 CHARLIE
104	5674	331223.76N 0443205.28E	38S MB 5684474287	Power transformer station	Clear	GOLF
105	5573	331214.48N 0443139.36E	38S MB 5573974003	Power transformer station	Clear	GOLF
106	5375	331253.64N 0443018.44E	38S MB 5360975220	Water treatment and pumping facility	Clear	GOLF
107	5373	331214.04N 0443009.08E	38S MB 5366174002	Ehtib burial site	Clear	GOLF
108	5775	331215.48N 0443225.16E	38S MB 5769474030	Air defense site	Clear	GOLF
109	5774	331236.00N 0443240.20E	38S MB 5785074660	Tuwaitha agricultural biological research center	Pending	GOLF
110	5774	331248.96N 0443229.48E	39S MB 6752276040	Baghdad SA-6 missile support facility	Clear	GOLF
111	5675	331300.84N 0443142.64E	38S MB 5606275432	Machine shop	Clear	GOLF
112	5575	331303.68N 0443138.32E	38S MB 5574775833	Khalid laboratory	Clear	
113	5375	331246.44N 0443010.44E	38S MB 5367575000	Al Hamath bio-pesticides production facility	Clear	GOLF
114	5474	331228.44N 0443045.00E	38S MB 5456772441	Environmental work shop	Clear	
115	5474	331239.24N 0443044.27E	38S MB 5454974774	Guard facility	Clear	GOLF
116	5474	331223.04N 0443100.12E	38S MB 5498774273	Annex for culture of plants and plant tissue	Clear	
117	5474	331223.04N 0443057.24E	38S MB 5488374273	Economic entomology and applied microbiology laboratory	Clear	
118	5474	331223.76N 0443059.04E	38S MB 5492974295	Personnel bunker	Clear	UGF, 5m x 27m
119	5474	331223.40N 0443047.88E	38S MB 5464074285	Personnel bunker	Clear	ALPHA
120	5474	331223.40N 0443030.23E	38S MB 5418974288	Animal pens and equipment storage	Clear	
121	5474	331224.12N 0443034.21E	38S MB 5428774303	Equipment and mechanical storage	Clear	
122	5375	331249.32N 0443007.16E	38S MB 5359175080	Guesthouse	Clear	GOLF
123	5475	331323.88N 0443038.52E	38S MB 5440775149	Unknown possible guard facility	Clear	GOLF
124	5575	331309.12N 0443701.44E	39S MB 5577475699	Unknown	Clear	GOLF
125	5775	331338.84N 0443418.84E	38S MB 5604575765	Nuked	Clear	GOLF
126	5774	331147.04N 0443222.24E	38S MB 5780573955	Main gate and guard facility	Clear	GOLF
127	5674	331227.36N 0443150.52E	38S MB 5628374400	Unknown possible military facility	Clear	GOLF
128	5674	331246.80N 0443155.36E	38S MB 5640574393	Unknown possible electrical maintenance	Clear	GOLF
129	5575	331300.84N 0443128.96E	38S MB 5570875434	Transportation department	Clear	GOLF
130	5675	331306.96N 0443140.48E	38S MB 5600775621	Unknown	Clear	GOLF
131	5575	331304.44N 0443109.48E	38S MB 5582075547	Unknown	Clear	GOLF
132	5475	331339.24N 0443038.64E	38S MB 5442476005	Unknown	Clear	GOLF
133	5573	331213.68N 0443117.36E	38S MB 5540373983	Barracks north of Fire Station	Destroyed	
134	5374	331220.16N 0443009.36E	38S MB 5364374180	Unknown	Clear	GOLF
135	5374	331229.88N 0442955.67E	38S MB 5382974491	Unknown	Clear	GOLF
136	5474	331243.32N 0443004.56E	38S MB 5423974313	Unknown	Clear	GOLF
137	5370	331159.64N 0443020.64E	38S MB 5293873557	Unknown	Clear	GOLF
138	5470	331145.24N 0443008.68E	38S MB 5426873112	Unknown	Clear	GOLF
139	5372	331122.24N 0443000.72E	39S MB 5341972440	Unknown possible warehouse	N/A	
140	5573	331157.48N 0443122.08E	38S MB 5552273483	Unknown	Destroyed	GOLF, Pile of rubble
141	5672	331120.48N 0443216.44E	38S MB 5632572335	Unknown	Clear	Grafin during recce
142	5772	331129.04N 0443230.12E	38S MB 5728072593	Agricultural research area	Clear	Grafin during recce

Results of mission survey of Tuwaitha Nuclear Complex over the period 20-22 November 2003. (continued)



Tuwaitha Nuclear Research Center

Building Numbers

BLD_NUMBER	GRID_REF	DMS	MGRS	PERCEIVED FUNCTIONALITY	STATUS	TYPE
142	5772	311123.04N 0443230.12E	38S MB 5726072539	Agricultural research area	Clear	Girlfin during recce
143	5672	311124.20N 0443953.41E	38S MB 5633072670	Housing area	Pending	GOLF; occupied by squatters
144	5772	311129.60N 0443229.24E	38S MB 5743972676	Unknown	N/A	
145	5873	311145.36N 0443256.44E	38S MB 5796372118	Unknown	N/A	
146	5773	311147.76N 0443237.32E	38S MB 5746372175	Unknown	N/A	
147	5772	311139.12N 0443242.72E	38S MB 5760872908	Unknown	N/A	
148	5673	311204.32N 0443206.36E	38S MB 5667073683	Unknown	Clear	GOLF
149	5573	311155.64N 0443104.81E	38S MB 5507573430	Unknown	Clear	GOLF
150	5273	311157.84N 0442944.88E	38S MB 5300672506	Unknown possible housing	N/A	
151	5573	311218.16N 0443119.20E	38S MB 5545073905	Fire station	Clear	GOLF
152	5574	311232.04N 0443123.72E	38S MB 5558074547	Possible fuel receiving bunker	Hazard	UGF. 22m x 40m x 3m hgt
153	5574	311228.88N 0443122.52E	38S MB 5556474447	Unknown possible guard facility	Clear	GOLF
154	5574	311215.28N 0443118.56E	38S MB 5542974643	Unknown	Clear	GOLF
155	5574	311215.28N 0443118.68E	38S MB 5543074643	Unfinished building, possible water treatment	Clear	GOLF
156	5575	311256.16N 0443103.24E	38S MB 5589975280	Unknown possible storage bunker	Clear	GOLF
157	5676	311304.44N 0443059.04E	38S MB 5646075541	Unknown	Clear	GOLF
158	5575	311200.00N 0443123.72E	38S MB 5552275500	Unknown possible administration research	Clear	GOLF
159	5576	311318.12N 0443121.72E	38S MB 5552475967	Unknown possible underground bunker	Clear	GOLF
160	5475	311303.36N 0443024.12E	38S MB 5403175519	Unknown possible dump site	Clear	GOLF
161	5476	311319.56N 0443038.08E	38S MB 5434176016	Unknown	Clear	GOLF
162	5475	311245.72N 0443028.08E	38S MB 5413974375	Unknown	Clear	GOLF
163	5473	311210.44N 0443058.68E	38S MB 5498773885	Connex container	Clear	Vest end of Bldg 37; ALPHA
164	5674	311245.72N 0443156.64E	38S MB 5642474365	Bl ath party building	Clear	GOLF
165	5373	311152.08N 0443017.28E	38S MB 5384473325	Unknown	Clear	GOLF
166	5574	311226.64N 0443103.72E	38S MB 5505174383	Unknown possible computer science center	Clear	ALPHA
167	5574	311235.84N 0443110.56E	38S MB 5522774050	Water purification and electrical sub-station	Clear	GOLF
168	5473	311201.44N 0443056.16E	38S MB 5488273608	Unknown possible storage	Clear	
169	5573	311206.64N 0443114.52E	38S MB 5532873772	Storage and water purification	Clear	
170	5473	311230.36N 0443048.36E	38S MB 5466974516	Small underground storeroom associated with bldg 54	Clear	UGF. Bio Team, CHARLIE
171	5474	311210.08N 0443105.16E	38S MB 5508673695	Reactor building	Destroyed	
172	5573	311144.16N 0443109.48E	38S MB 5519473074	Fire station burial site	Clear	GOLF
173	5475	311250.04N 0443034.28E	38S MB 5429075308	Burial site	Clear	GOLF
174	5475	311256.88N 0443051.48E	38S MB 5472875316	Burial site	Clear	GOLF
175	5575	311300.48N 0443138.28E	38S MB 5598175421	Shumokh stores	Clear	GOLF
176	5575	311309.12N 0443129.64E	38S MB 5572875688	Secondary gate guard facility	Clear	GOLF
177	5373	311158.28N 0442950.36E	38S MB 5317473516	Hot waste burial site	Clear	GOLF
178	5674	311222.32N 0443204.30E	38S MB 5663574243	Bl ath party building	Clear	GOLF
179	5875	311253.64N 0443205.40E	38S MB 5820575201	Temporary fuel storage, questionable location	N/A	
180	5474	311216.16N 0443046.08E	38S MB 5458574541	Utilities for Bldg 54 and storage	Clear	ALPHA; MAJ Accardi
181	5473	311210.44N 0443052.64E	38S MB 5478073888	Large cloner container	Clear	
182	5474	311240.32N 0443043.20E	38S MB 5452274807	Unknown buildings at 115	Clear	GOLF; occupied by squatters
183	5474	311212.24N 0443047.84E	38S MB 5464074219	Above ground Earth mounded Personnel bunker	Clear	UGF. 27m x 9m
184	5474	311220.16N 0443049.36E	38S MB 5467774189	Above ground Earth mounded bunker	Clear	UGF. Water/Fuel storage, 8.5mDIA 3m hgt
185	5474	311219.08N 0443050.04E	38S MB 5466674152	Above ground Earth mounded bunker	Clear	UGF. Water/Fuel storage, 8.5mDIA 3m hgt
186	5474	311218.72N 0443052.24E	38S MB 5467274141	Above ground Earth mounded Personnel bunker	Clear	UGF. Storage, 5m x 27m
187	5474	311218.28N 0443055.76E	38S MB 5468474063	Above ground Earth mounded bunker	Clear	UGF. Water/Fuel storage, 11mDIA 3m hgt
188	5474	311215.84N 0443055.08E	38S MB 5468274052	Above ground Earth mounded bunker	Clear	UGF. Water/Fuel storage, 11mDIA 3m hgt
189	5474	311215.12N 0443053.64E	38S MB 5467974030	Above ground Earth mounded bunker	Clear	UGF. Water/Fuel storage, 6mDIA 3m hgt
190	5474	311214.76N 0443054.08E	38S MB 5467874018	Above ground Earth mounded bunker	Clear	UGF. Water/Fuel storage, 6mDIA 3m hgt

Results of mission survey of Tuwaitha Nuclear Complex over the period 20-22 November 2003. (continued)

Tuwaitha Nuclear Research Center

Building Numbers

GRID_REF	DMS	MGRS	PERCEIVED FUNCTIONALITY	STATUS	TYPE
5474	331214.76N 0443054.04E	38S MB 5473874016	Above ground Earth mounded bunker	Clear	UGF, Water/Fuel storage, 6mDIA 3m hgt
5474	331203.60N 0443042.04E	38S MB 5450773676	Above ground Earth mounded Personnel bunker	Clear	UGF, Storage, 9m x 6m x 1m hgt
5276	331201.08N 0443034.76E	29S MB 5278073602	Above ground storage bunker	Clear	UGF, Storage, 22m x 20m, GOLF
5473	331209.72N 0443054.00E	38S MB 5474773662	Conver container	Clear	Closest building is 192 and 76; Unlocated by Aucardi
5474	331229.52N 0443054.36E	38S MB 5488974473	Above ground Earth mounded bunker	Clear	UGF, Confirmed water storage, 13mDIA 3m hgt
5573	331207.56N 0443118.20E	38S MB 5526737395	Above ground Earth mounded Personnel bunker or storage	Clear	UGF, Water/Fuel storage, 6mDIA 3m hgt
5573	331214.04N 0443109.48E	38S MB 5519873895	Above ground Earth mounded Personnel bunker or storage	Clear	UGF, Water/Fuel storage, 6mDIA 3m hgt
5573	331210.08N 0443111.64E	38S MB 5524473895	Above ground Earth mounded Personnel bunker or storage	Clear	UGF, Water/Fuel storage, 6mDIA 3m hgt
5573	331212.68N 0443108.04E	38S MB 5516173950	Underground facility	Clear	UGF, 60m x 45m
5473	331157.84N 0443046.76E	38S MB 5460573502	Bollet house	Clear	
5474	331218.36N 0443042.12E	38S MB 5449174131	Above ground Earth mounded bunker	Clear	UGF, Waste water, 5.5m DIA 3m hgt
5474	331237.64N 0443029.52E	38S MB 5418474110	Possible above ground Earth mounded bunker	Clear	UGF, identified by DTRA as possible small generator bldg
5474	331229.52N 0443046.08E	38S MB 5455574474	Below ground concrete covered bunker between 55 and 54	Clear	UGF,
5573	331209.72N 0443118.20E	38S MB 5526873861	Large below ground concrete covered bunker	Clear	UGF,
5573	331218.24N 0443106.96E	38S MB 5513073939	Underground facility under building 24	Clear	UGF,
5474	331232.04N 0443039.60E	38S MB 5442774553	Underground facility under building 96	Clear	UGF,under building, storage, BRAVO

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Annex E
Summary of Known UN-Tagged Equipment

UN Tag	Equip	Location	Current Status	Remarks
B000194*	Biosafety Cabinet, Class II	Bldg 18 Rm 202	Not Found	Past Use: 4 years' research work Hydrocarbon degradation, Present Use: As in the past, Future Use: As in the past. This item not listed by UNSCOM 87 and not declared.
B000195*	Incubator, shaker 20L	Bldg 18 Rm 202	Not Found	Past Use: Used for hydrocarbon degradation (research), Present Use: As in the past, Future Use: As in the past.
B000196*	Incubator, shaker 6L	Bldg 18 Corridor 1st Floor Rm 3	Not Found	Past Use: For Rhizobium cultivation/ production—for research, Present Use: Out of order, Future Use: To be repaired for use as in the past.
B000197*	Biosafety Cabinet, Class II	Bldg 4 Rm 120	Not Found	Past Use: Analyze production and research and other enzymes, Present Use: As in the past, Future Use: As in the past.
B000198*	Incubator (tagged in error)	Bldg 4 Rm 120	Not Found	Past Use: Enzyme production research, Present Use: As in the past, Future Use: As in the past. Tagged in error. (not a SHAKER incubator as reported by UNSCOM 87).
B000199*	Biosafety Cabinet, Class II	Bldg 47 Rm - UNKNOWN	Not Found	Past Use: Vaccine production from egg embryos, Present Use: As in the past, Future Use: As in the past.
B000200*	Dryer, freeze	Bldg 50 Rm 15	Not Found	Past Use: Drying of food samples, baby food etc, Present Use: As in the past, Future Use: As in the past.
B000201*	Dryer, freeze 2L	Bldg 60 Rm 33, ground floor	Present	Past Use: Radio Pharmaceuticals freeze drying, Present Use: As in the past, Future Use: As in the past.
B000202*	Dryer, freeze 2-3L	Bldg 18 Rm 3	Not Found	Past Use: Rhizobium freeze-drying research, Present Use: As in the past, Future Use: As in the past. Earlier UNSCOM team stated machine not taggable.
B000304	Shaker, Orbital 10L (Top Opening/ Steel)	Bldg 4 Corridor	Not Found	Past Use: Rennin production from bacteria. Present Use: Rennin production from bacteria. Future Use: Rennin production. Origin: Purchased new, over 10 years ago.
B000305	Incubator, illuminated Cooled Orbital	Bldg 4 Corridor across from Rm 106	Not Found	Past Use: Used for starter cultures for B. thereigersis and single cell protein. Present Use: Autrophic bacteria for metal leaching. Future Use: Autrophic bacteria for metal leaching.
B000306	Shaker, Incubator 5L (Front Opening)	Bldg 50 Corridor	Not Found	Past Use: Growing cultures. Present Use: Not working. Future Use: If spare parts become available, will repair. Origin: Bought new around 1974, imported.

Summary of Known UN-Tagged Equipment (continued)				
B000307	Shaker, Incubator 0.01-0.02 m3 (Top Open)	Bldg 18 Rm 208	Not Found	Use: For thermophilic bacteria, thermos table enzyme production, particularly heamocelluloses. Origin: Arrived 10 years ago. Note: Although model no. is overwritten by 101, 141 is seen and correct.
B000399	Vessel, Double Jacketed	Biological Pesticide Building	Not Found	Awaiting tag sheet for further record input
B000400	Vessel, Double Jacketed	Biological Pesticide Building	Not Found	Awaiting tag sheet for further record input
B000401	Vessel, Double Jacketed	Biological Pesticide Building	Not Found	Awaiting tag sheet for further record input
B000402	Vessel, Double Jacketed	Biological Pesticide Building	Not Found	Awaiting tag sheet for further record input
B000403	Vessel, Double Jacketed	Biological Pesticide Building	Not Found	Awaiting tag sheet for further record input
B000404	Vessel, Double Jacketed	Biological Pesticide Building	Not Found	Awaiting tag sheet for further record input
B000405	Vessel, Double Jacketed	Biological Pesticide Building	Not Found	Awaiting tag sheet for further record input
B000406	Vessel, Double Jacketed	Biological Pesticide Building	Not Found	Awaiting tag sheet for further record input
B000407	Vessel, Double Jacketed	Biological Pesticide Building	Not Found	Awaiting tag sheet for further record input
B001501*	Biosafety cabinet, Class II	Bldg 4 Rm 104	Not Found	
B001502*	Sequencer, DNA (Electrophoresis Unit)	Bldg 4 Rm 108	Not Found	The unit will be used for DNA sequencing as soon as some ordered parts arrive. Equipment was imported 5 yrs ago. Never used.
B001503*	Fermenter, 18 L.	Bldg 4 Rm 106	Bldg 171, Underground Store, Damaged	
B001504*	Fermenter, 5 L.	Bldg 4 Rm 106	Bldg 171, Underground Store, Damaged	*
B001505*	Fermenter, 20 L.	Bldg 4 Rm 106	Found	
B001506*	Fermenter, 20 L.	Bldg 4 Rm 106	Found	
B001507*	Fermenter, control unit	Bldg 4 Rm 106	Not Found	Consists of 5 components: peristaltic pump; temp control unit; Pl4 control unit; PO2 control unit; stirrer speed control and flow control
B001508*	Dryer, Freeze	Bldg 4, Corridor	Not Found	

Summary of Known UN-Tagged Equipment (continued)				
B001510*	Dryer, freeze (small)	Bldg 4 Corridor	Not Found	
B001511*	Fermenter, 3 x 15 L.	Bldg 18 Rm 206	Not Found	5N control: 58244; chamber 58507(F7-100); 58508(F7-100); 58509(F7-100)
B001512*	Dryer, Lyophilizer (small) Stoppering Tray	Bldg 60 Rm 24, 1st floor	Not Found	
B001513*	Dryer, freeze, bottom	Bldg 60, Rm 24, 1st floor	Not Found	
B001514*	Dryer, freeze (1 m3)	Bldg 56	Not Found	
B002012	Shaker, Water Bath 5L +	Bldg 4 Rm 104 Laboratory	Not Found	Past Use: Growing molds and bacteria for enzymes. Present Use: Not working. Future Use: Easily repaired when spare parts become available. Origin: Unknown.
B002103	Dryer, Spray 1.5 cu m	Bldg 53 Chemical pilot plant	In Situ	Past Use: Not used, made at Tuwaitha workshops. Present Use: not used. Future Use: Unknown
B002104	Centrifuge, Continuous Flow	Bldg 53 Chemical pilot plant	In Situ	Past Use: Date syrup purification. Present Use: Stored. Future Use: Unknown
B002113	Shaker, Incubator	Bldg 60, Rm 11, ground floor	Found	Past Use: Found in destroyed buildings. Present Use: Not in use. In the future: Shaking of liquids only (No microorganisms)
B002123	Dryer, Freeze	Bldg 4	Not Found	
B002146	Particle Sizer, Aerodynamic	BLDG 59, RM 8	Not Found	
B002147	Dispenser, Powder, Small Scale	Bldg 39, Rm 8	Bldg 59, Room 1	Measures concentration of particle sizes, for dust concentrations.
B002218	Computerized Central Control Unit for Feri	Bldg 59 Rm 5	Not Found	
B002228	Filter Press	Bldg 71	Found	
B002236	Incubator, Shaker	Bldg 90	Not Found	
B002435	Shaker, Reciprocating (Two tiered for 8L)	Bldg 18 First Floor - Microbiology (Room 3)	Not Found	
B002443	Fermenter, double jacketed, Steel(400 L)	IAEC Workshop, outside the site	Not Found	

Summary of Known UN-Tagged Equipment (continued)				
B002444	Fermenter, double jacketed, Steel (150 L)	IAEC Workshop, Bldg 53	In Situ	
B002445	Fermenter, double jacketed, Steel (150 L)	IAEC Workshop, Bldg 53	In Situ	
B002446	Fermenter, double jacketed, Steel (700 L)	IAEC Workshop, Outside bldg 53	Inside Bldg 53	
B002493	Fermenter, double jacketed, Steel (120 L)	Bldg 53	In Situ	Used in the purification of ethanol.
B002497	Dryer, Freeze, Lyophilizer	Bldg 18, 1st Floor Rm 206	Not Found	Dr Alaa Sharif is responsible for this freeze dryer.
B002498	Vessel, double jacketed, steel	Bldg 53	In Situ	
B002419	Incubator, shaker	Media Prep Bldg, Hall, Plant Tissue Station	Not Found	This piece of equipment appears to be declared by Tuwaitha and is stated to be untagged and not functional.
B002471	Shaker, orbital	Incubation Room	Not Found	
B002472	Shaker, orbital	Bldg 50 Section B	Not Found	

Note: Not found implies that a particular item was not positively identified. This may have been due to the removal of the label or the fact that the equipment was not present or may have been destroyed/relocated.

Annex F
Photography Highlights:
Tuwaitha Mission,
20-22 November 2003

Building 37, Room 1. *Crane outside room 1, pans/base, and water pumps.*

Building 37, Room 3. *Distillation columns, technicatiome items, and heat exchangers.*

Building 163 (connex): *Shipping crate (connex) (top left), digital equipment (top center and top right), high-voltage system (bottom left), and vacuum pumps (bottom right).*

Building 53, Room 1. *Water filtration system, processing tank, and press.*

Building 53, Room 1. *Bathtubs and dryer (left); clove oil production equipment (center and right).*

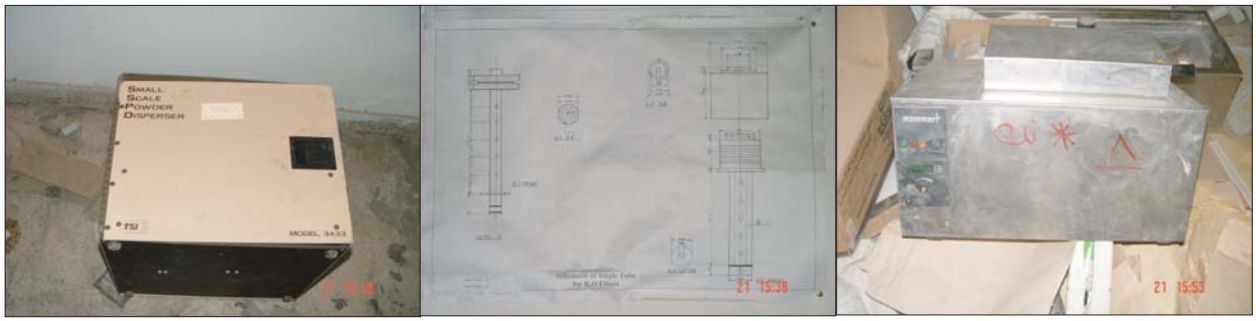
Building 53, Room 1. *Water-processing system (left and center); press (right).*

Building 53, Room 1. *Production of lipton wax (left and center); zinc oxide production (right).*


Building 53, Room 1. *Dryer (left) and pressure vessel (right).*


Building 53, Room 9. *Chemical laboratory (left) and lab-processing equipment (right).*

Building 16: *Festo pneumatic valves, table saw (bottom left), and liquid nitrogen bottle .*



Building 59: *Power dispenser (R1), reverse osmosis schematic (R3), and oven/incubator (R9).*

Building 59: *Stirrers (R9), hotplates and fermaldehyde (R9), and biohazard sticker (R11).*

Building 59: *Bacteriology laboratory (R14), chem/bio laboratory (R15), and chemicals (R15).*

Building 59: *Fume hood (R17), protected lab (R19), and brucella medium base (R20).*

Building 59: *Unidentified equipment (R23), water softener (R23), and autoclave? (R23).*

Building 59: *Reverse osmosis laboratory (R29) (left and center); burnt metal cases (R31) (right).*

Building 59: *Unidentified burnt equipment (R32), unidentified equipment (R40), and distilation equipment (R42).*

Building 59: *Rad. source-led cave (R45).*

Building 59: *Hallway; unidentified equipment, dose rate meter, and unidentified equipment.*

Building 167, Room 2. *Americium-241 radiological source on desk.*

Building 17, Room 2. *Mechanical/plumbing workshop.*

Building 17: *Mechanical/woodwork workshop (R19) (left and center); unidentified gas bottle (R16) (right).*

Building 17: *Tammuz/cooling tower (Osirak) (left and center); Tammuz-2 (ISIS) (right).*

Building 3: *Germanium detector cryostat (R24).*
Building 82: *Possible missile transportation canister (R4).*
Building 7: *Burned room.*

Library (from berm), bunker (behind building 167), and view from berm.

11 November 2003 Mission: *Optical spectrometer (near building 90; in report), Anderson sampler (dump near main entrance).*

Annex G
Tuwaitha Maps, Buildings, and Numbers

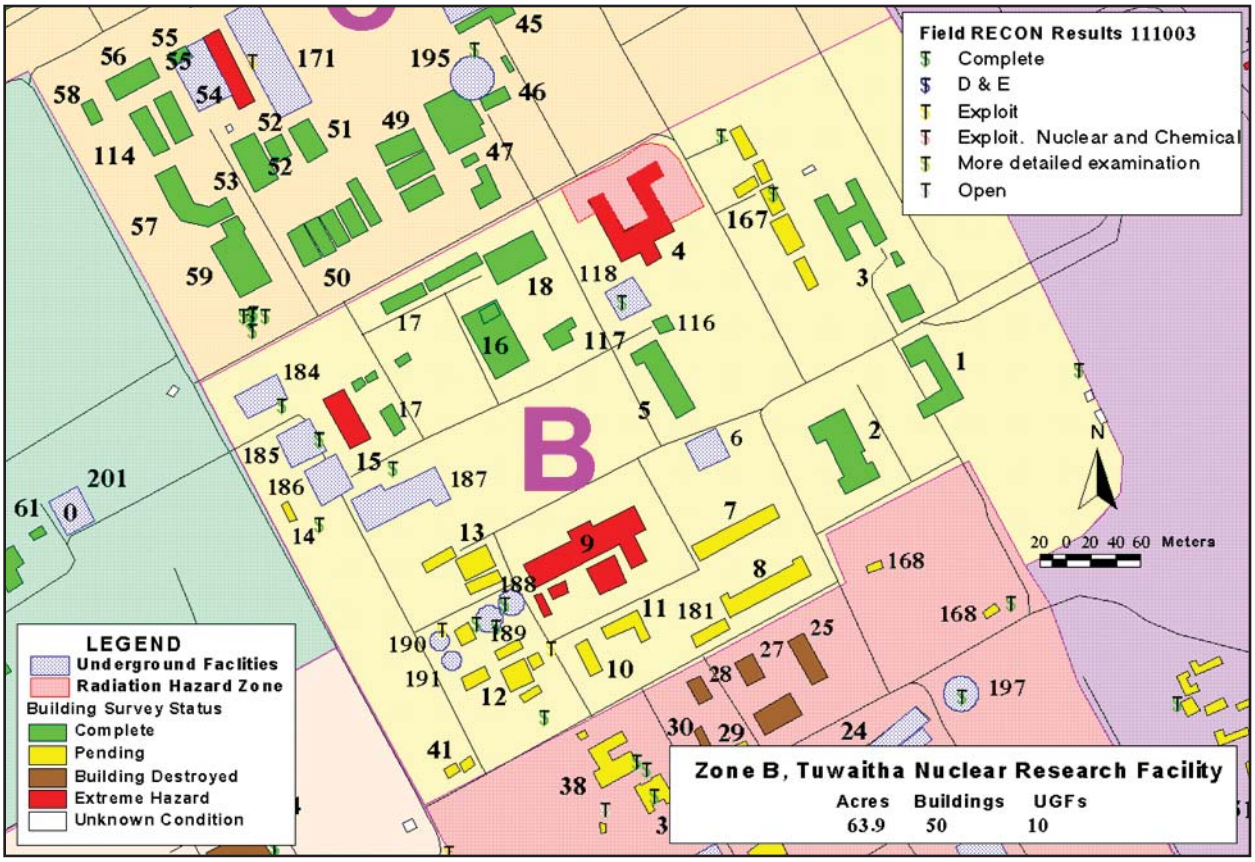


Figure 43. *Tuwaitha Complex—Zone B (status of buildings before the 20-22 November 2003 survey mission).*

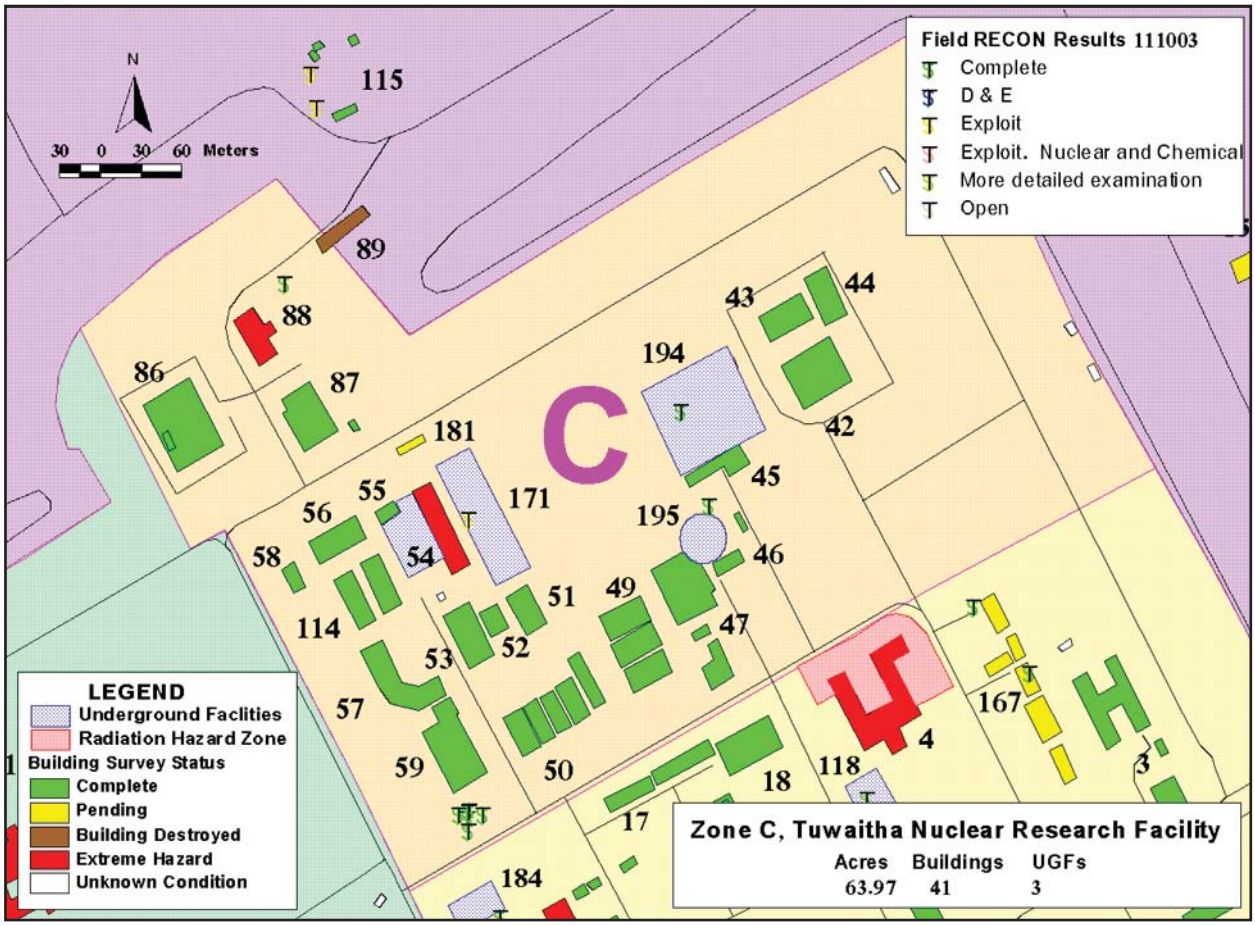


Figure 44: *Tuwaitha Complex—Zone C (status of buildings before the 20-22 November 2003 survey mission).*

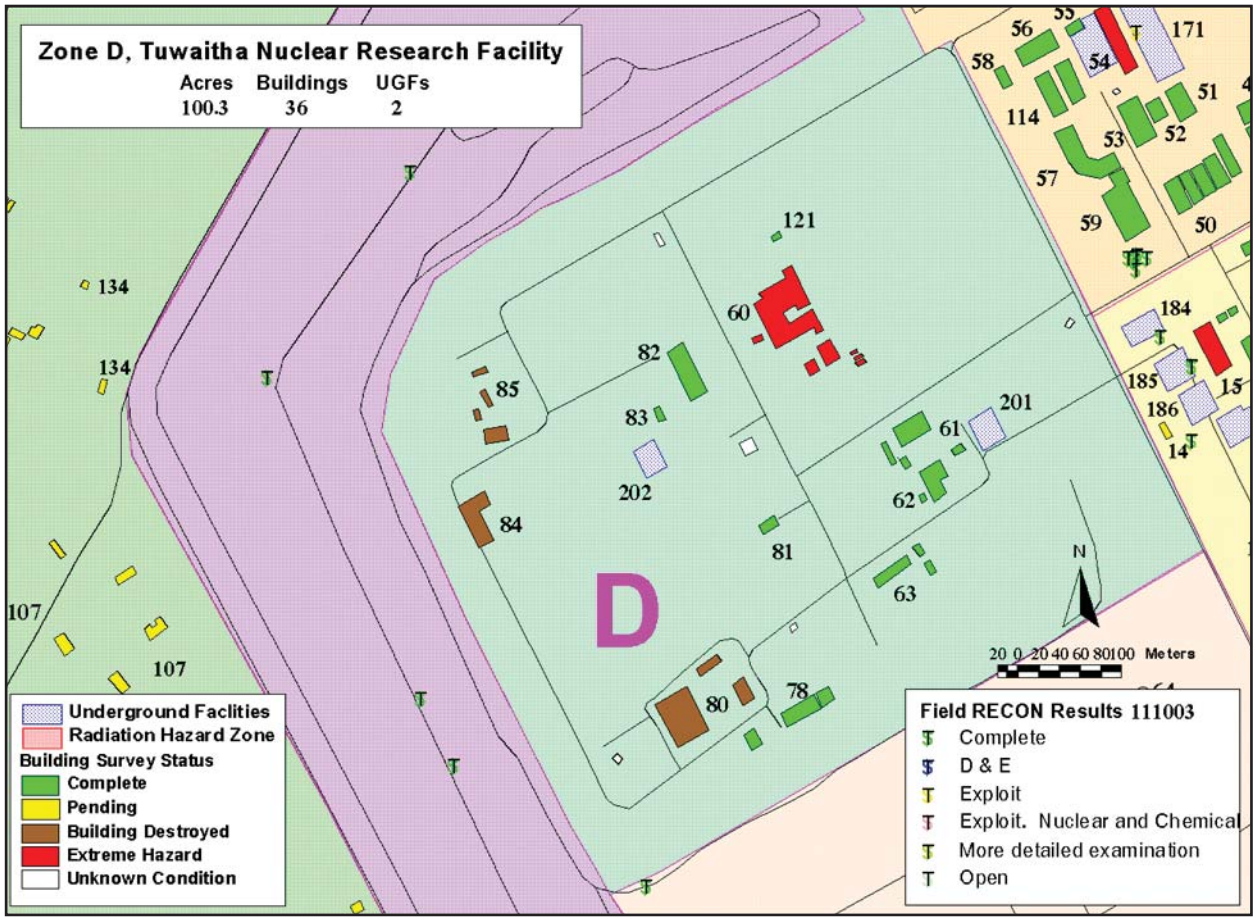


Figure 45: *Tuwaitha Complex—Zone D (status of buildings before the 20-22 November 2003 survey mission).*

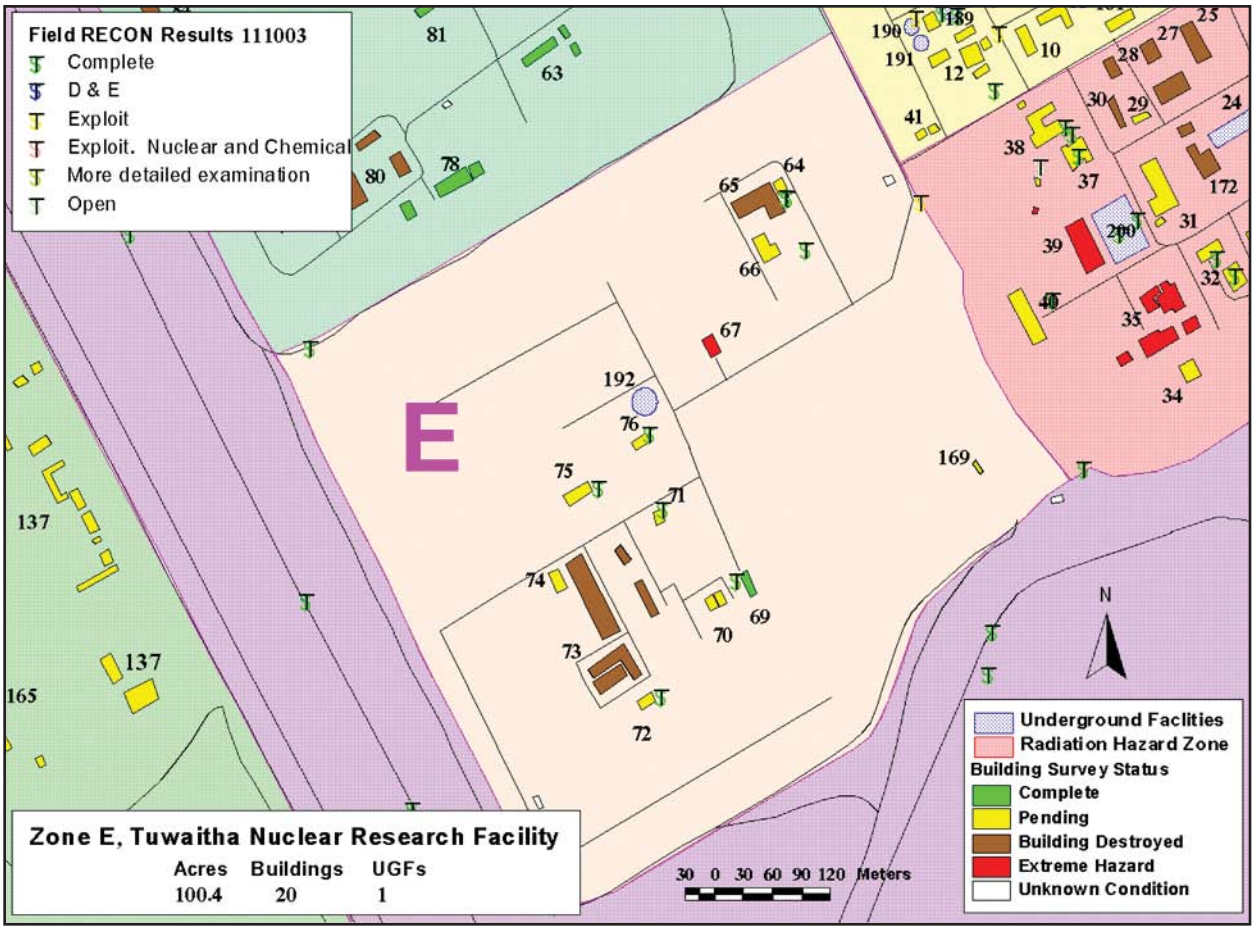


Figure 46: *Tuwaitha Complex—Zone E (status of buildings before the 20-22 November 2003 survey mission).*

Team Safety

- All entry team members were fitted with dosimeters set to a minimum alarm level of 0.1 mR/Hr. Team Leaders carried a second dosimeter issued by civilian consultants.

- All personnel were instructed firmly not to enter any Hazard areas and to leave any building immediately, if their dosimeter alarms were triggered, and to call out the radiation Quick Response Force (QRF) established in the CP at the living accommodation on site. Teams were allowed to enter buildings defined as a caution only with an approved ISG escort.

- All persons, leaving the vicinity of Building 2 (our accommodation), were monitored for contamination before entering living area on return.

Dosimeter readings were recorded as the dosimeters were collected at the end of the mission.

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