Comprehensive Report

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

30 September 2004

volume II of III

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

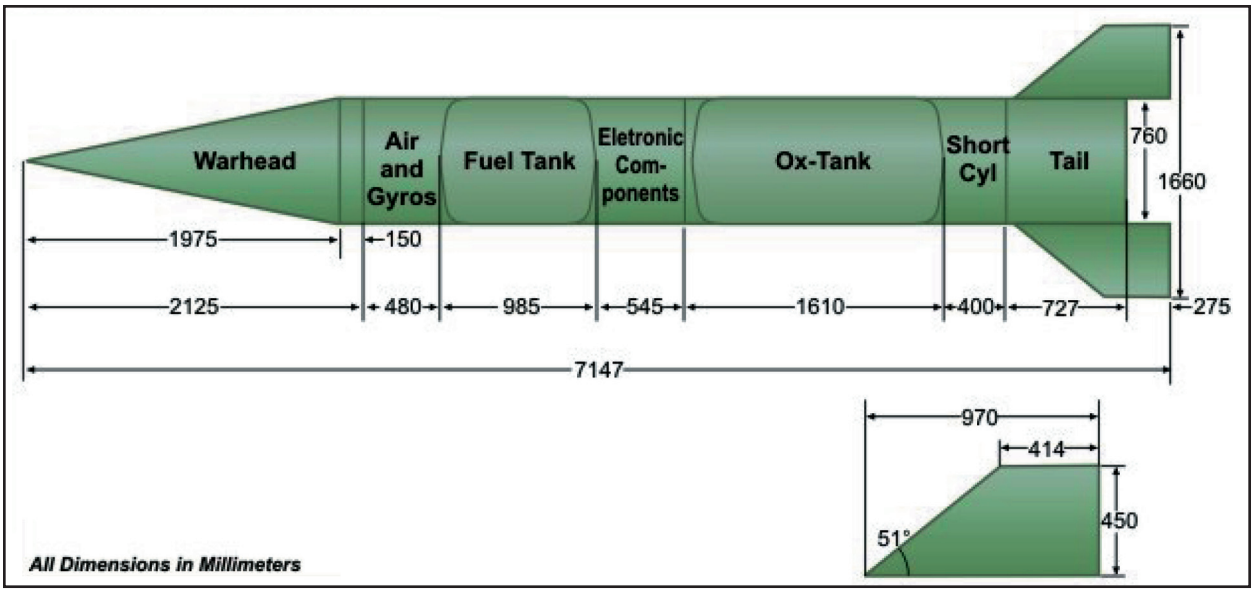

Figure 1. *Al Samud II diagram.*

Figure 2. *Al Samud II.*

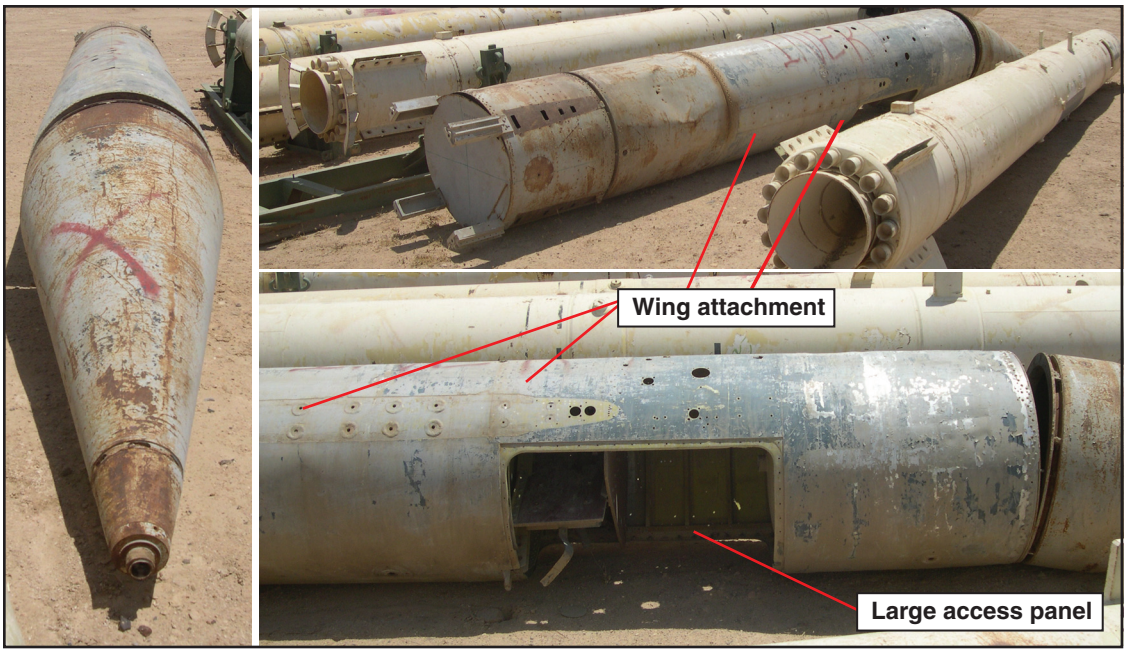

Figure 3. *Early Al Samud II using HY-2 airframes.*

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.

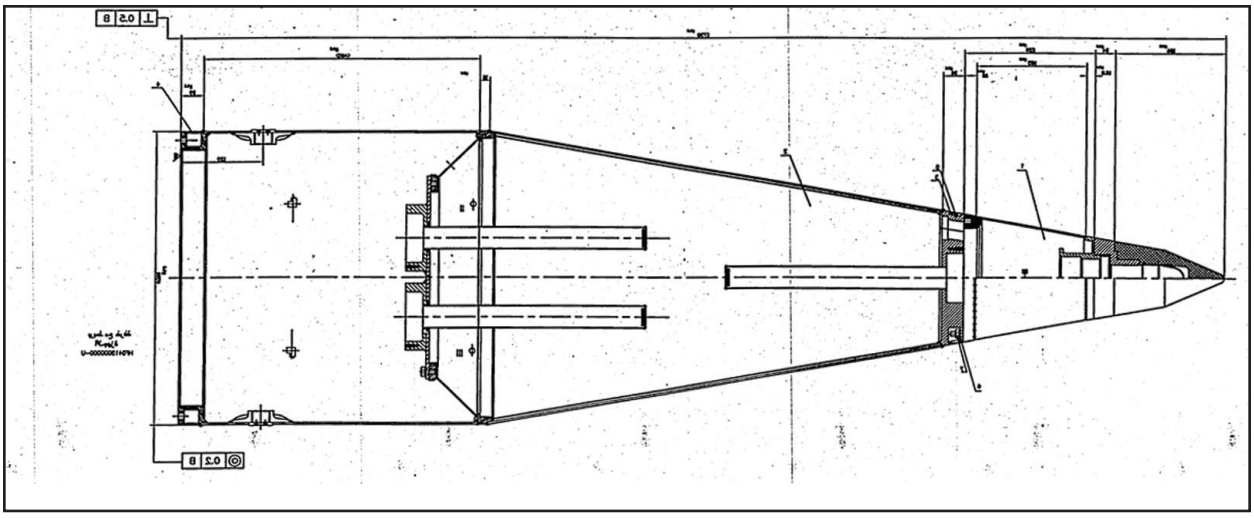

Figure 4. *Al Samud warhead design.*

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.

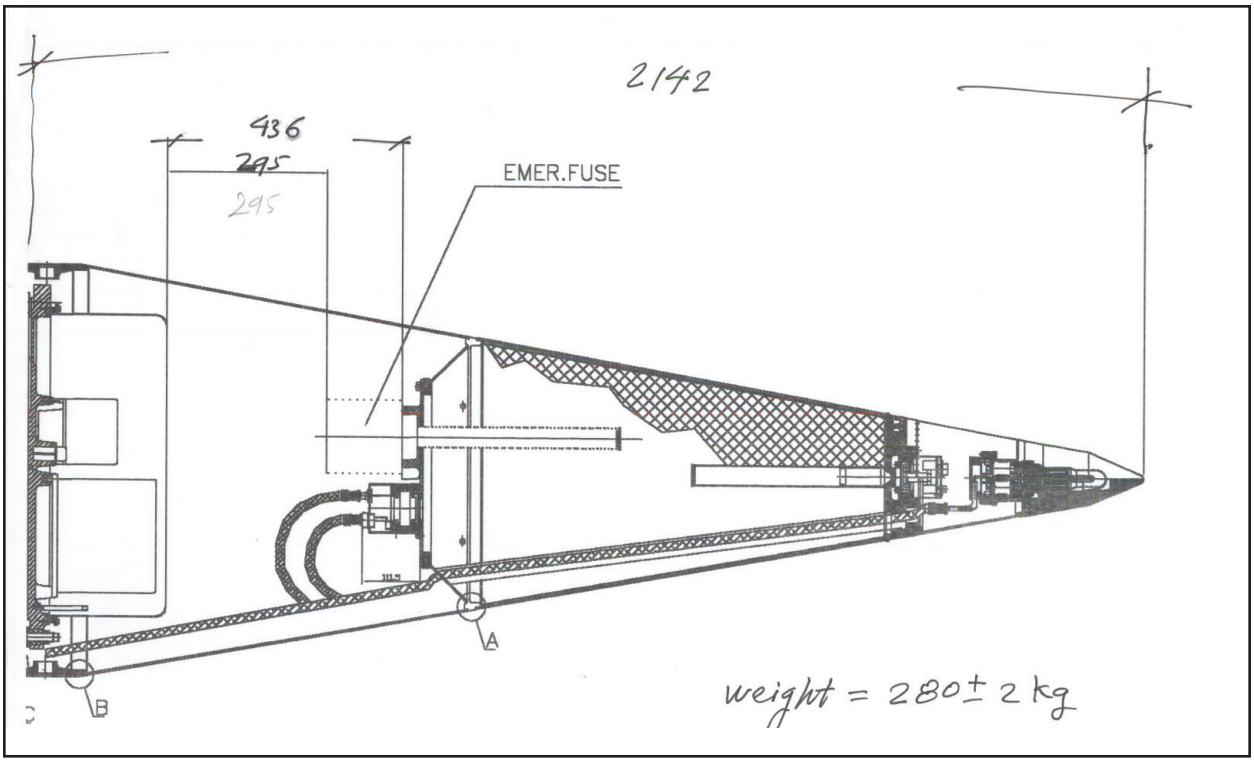

Figure 5. *Al Samud II warhead.*

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 Iraqu 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.

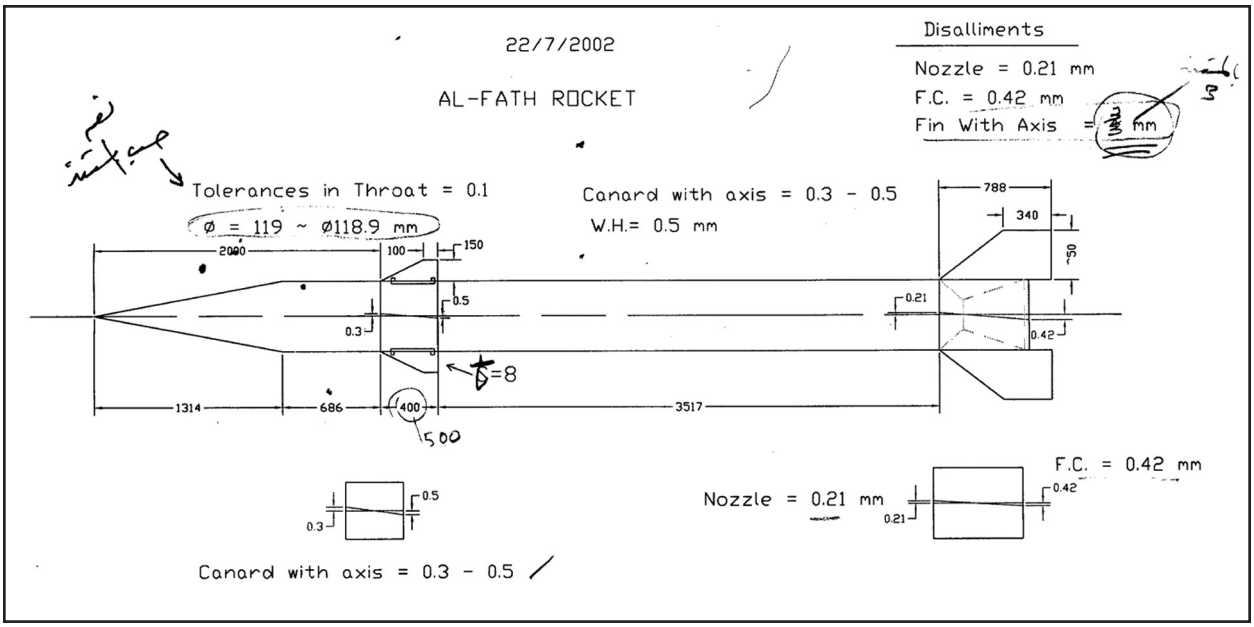

Figure 6. *Al Fat'h missile.*

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.

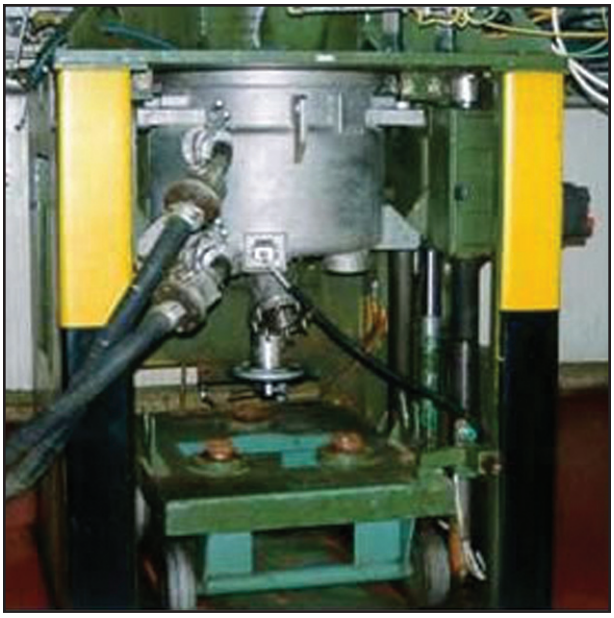

Figure 8. *30-gallon/100-liter propellant mixer bowl.*

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.)

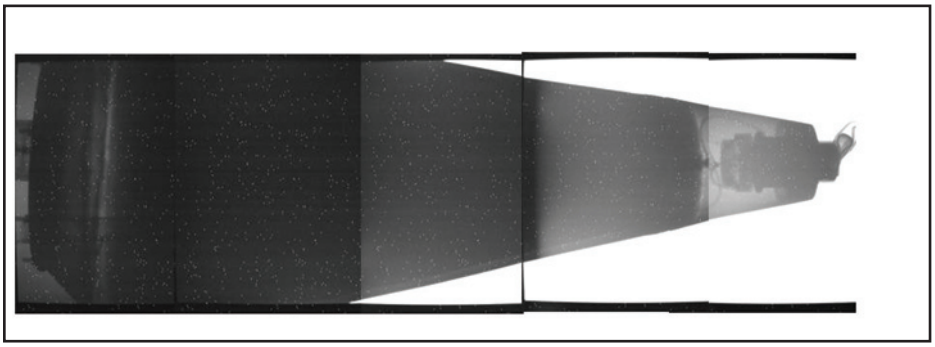

Figure 10. *X-ray of Al Fat'h unitary HE warhead.*

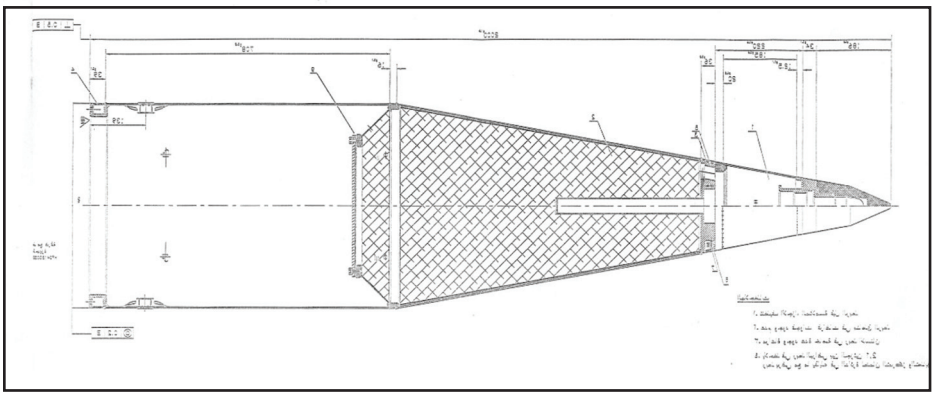

Figure 11. *Al Fat'h HE warhead.*

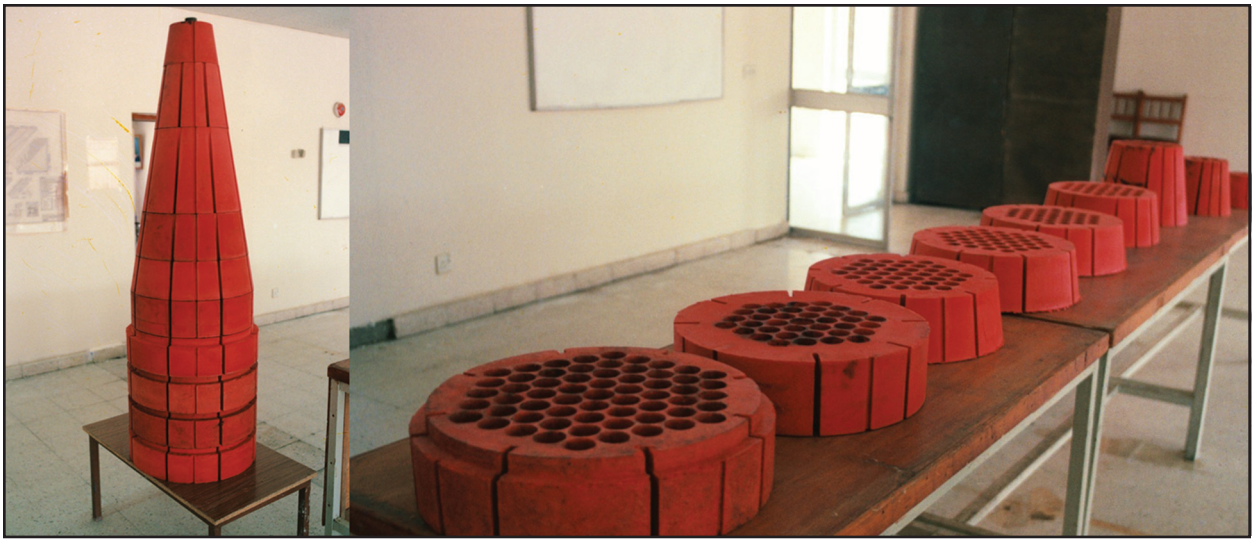

Figure 12. *Lightweight foam moldings used in the Al Fat'h warhead.*

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.

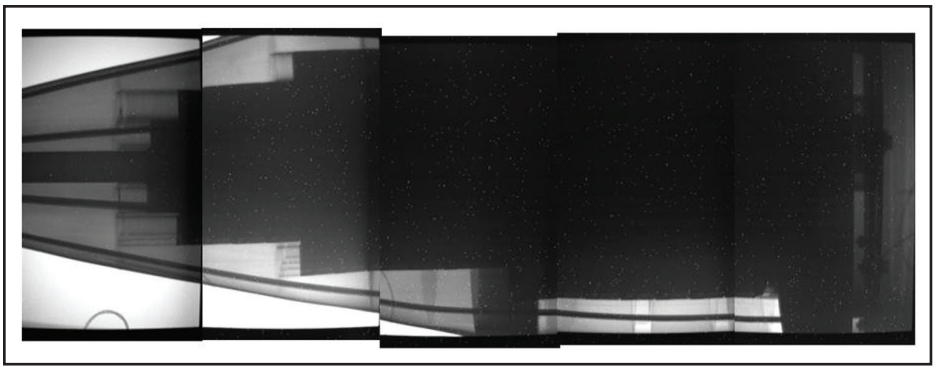

Figure 14. *X-ray of Al Fat'h submunitions warhead aeroshell.*

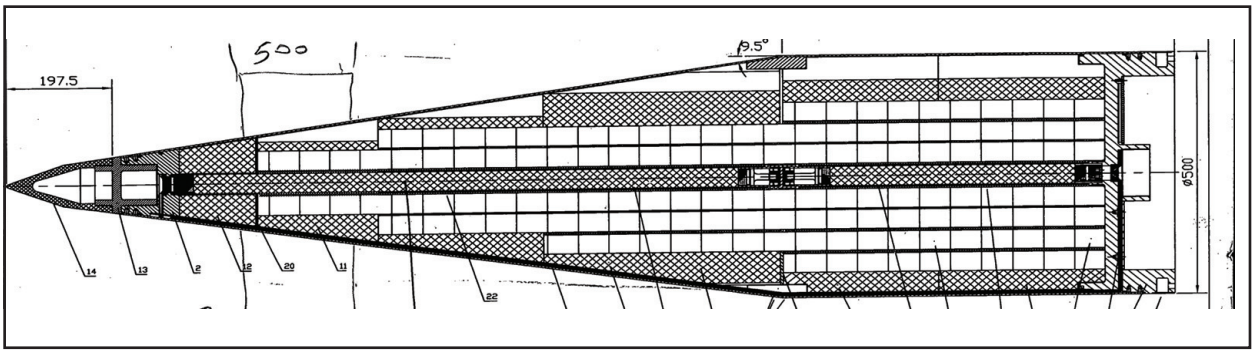

Figure 15. *Design drawing of the Al Fat'h submunition warhead.*

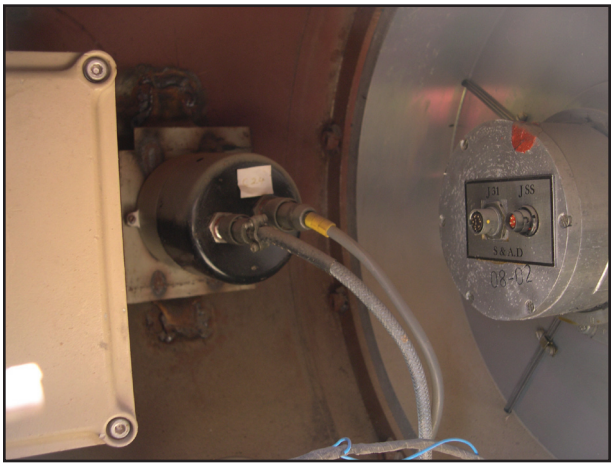

Figure 16. *Submunition warhead safe, arm, fuze, and fire system located at the base of the warhead.*

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 and in December of that year. However, other documentation not forwarded to Huwaysh had been recovered by ISG.

- Huwaysh ordered at the onset of OIF that all the documents on the long-range missile project be destroyed, 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 secret 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.***

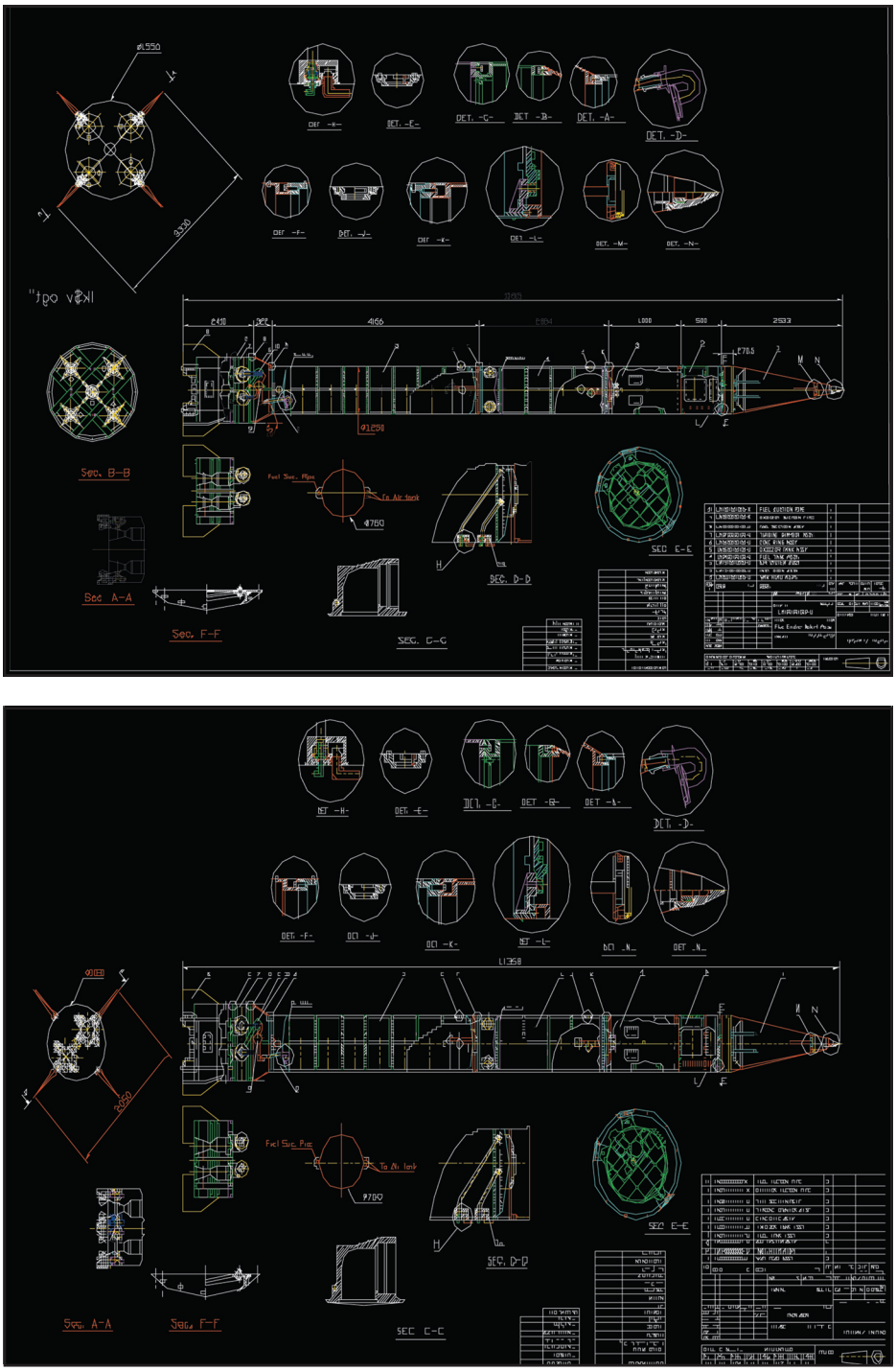

Figure 18. *Design drawings for two-and five-engine cluster missile.*

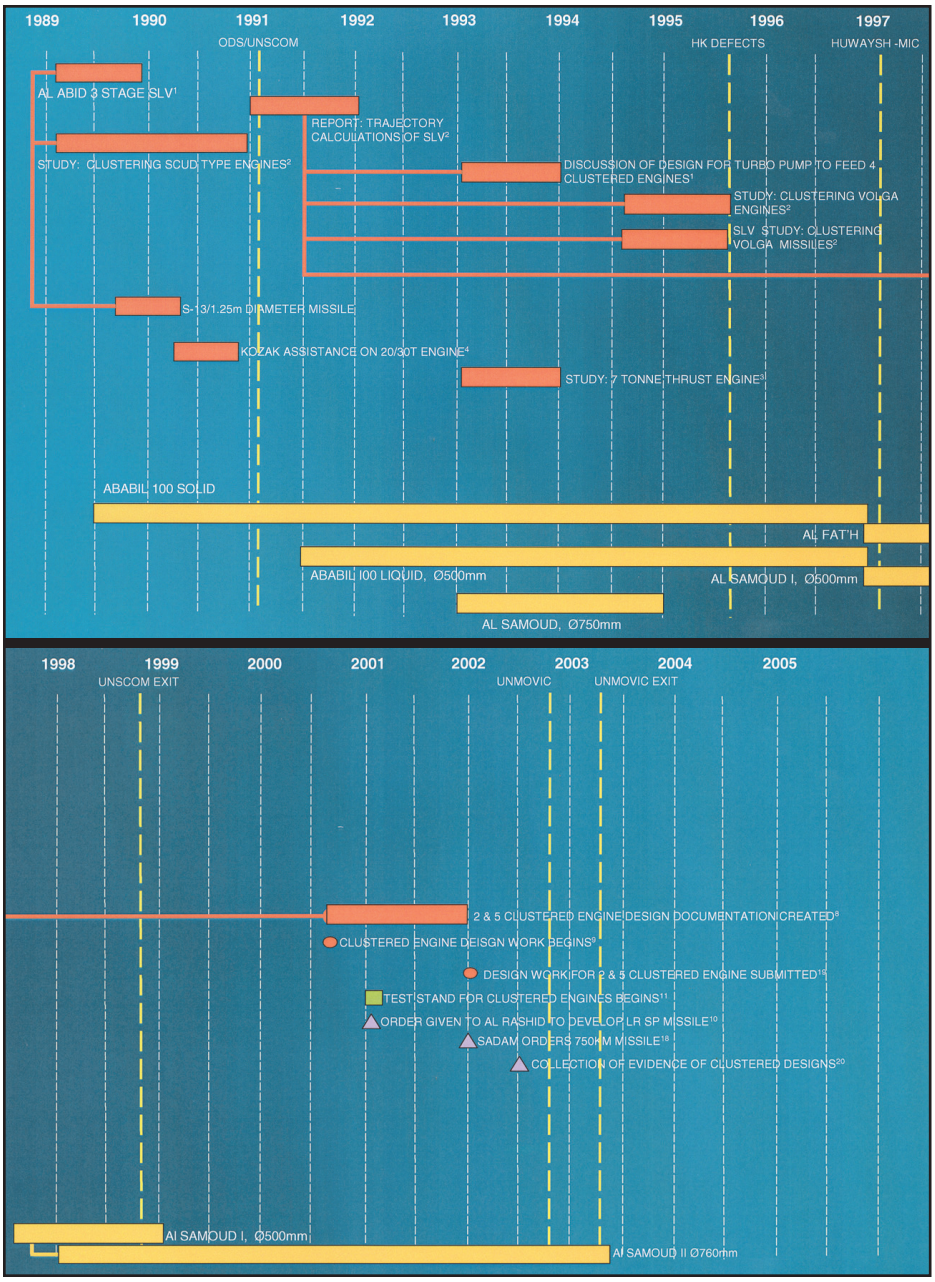

Figure 19. *Liquid-propellant long-range missile chronology.*

- 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 three exceptions. One senior Iraqi specifically stated the missile was developed for a chemical payload, while two 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.

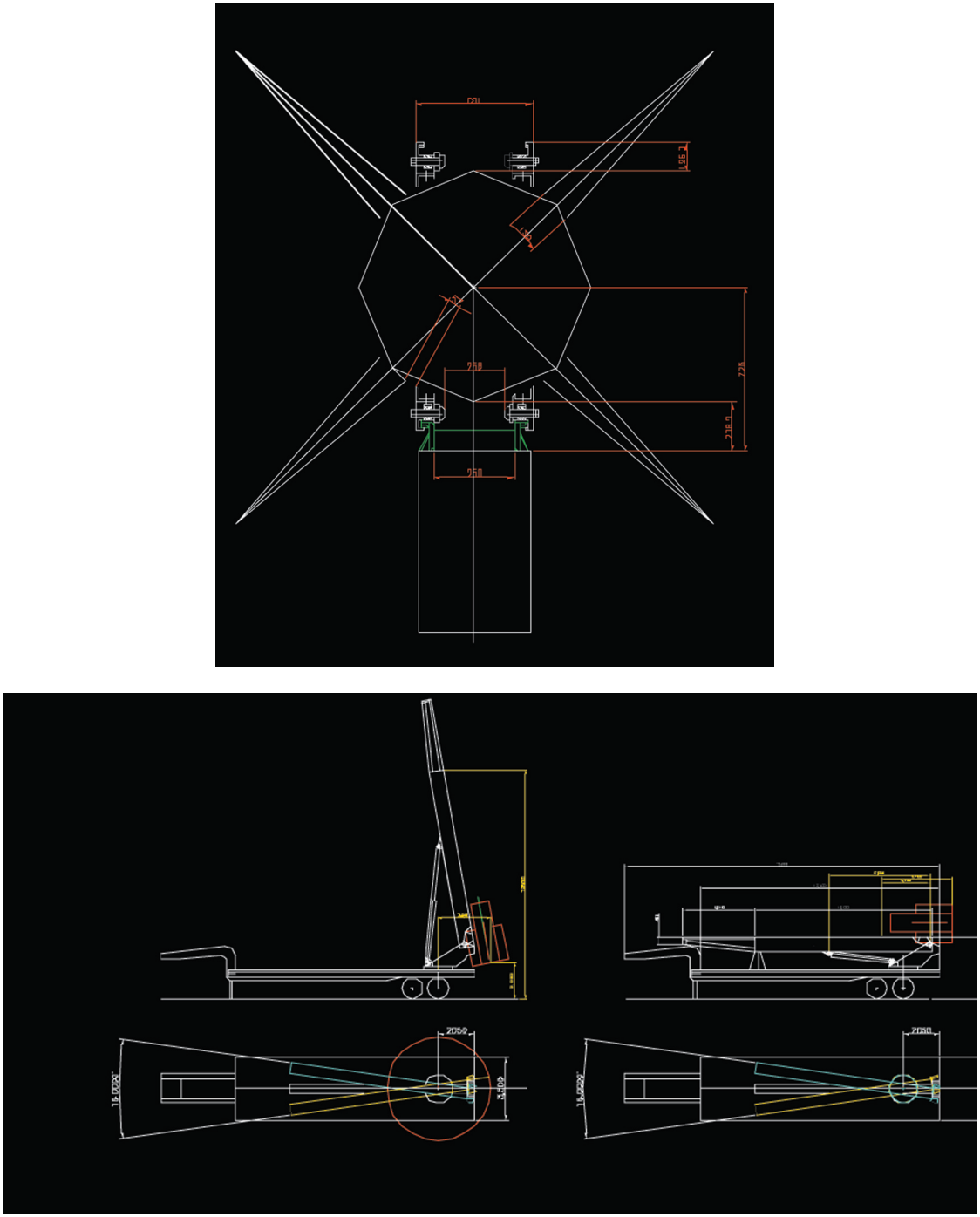

Figure 20. *Designs for long-range solid-propellant missile launcher.*

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.

- The extended-range HY-2 program if during flight tests did not exceed 150 km 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.

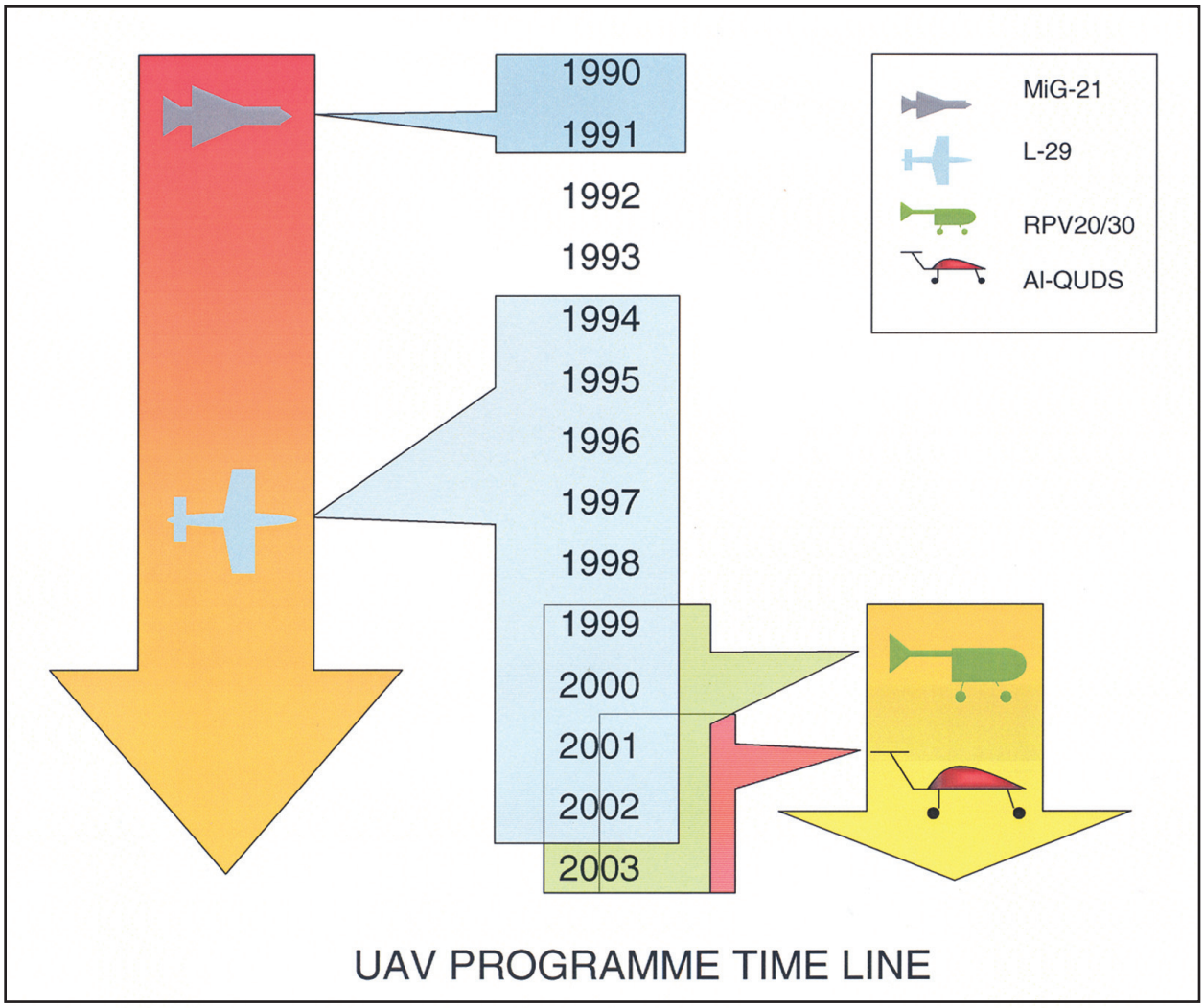

Figure 21. *Iraqi UAV programs.*

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 was 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

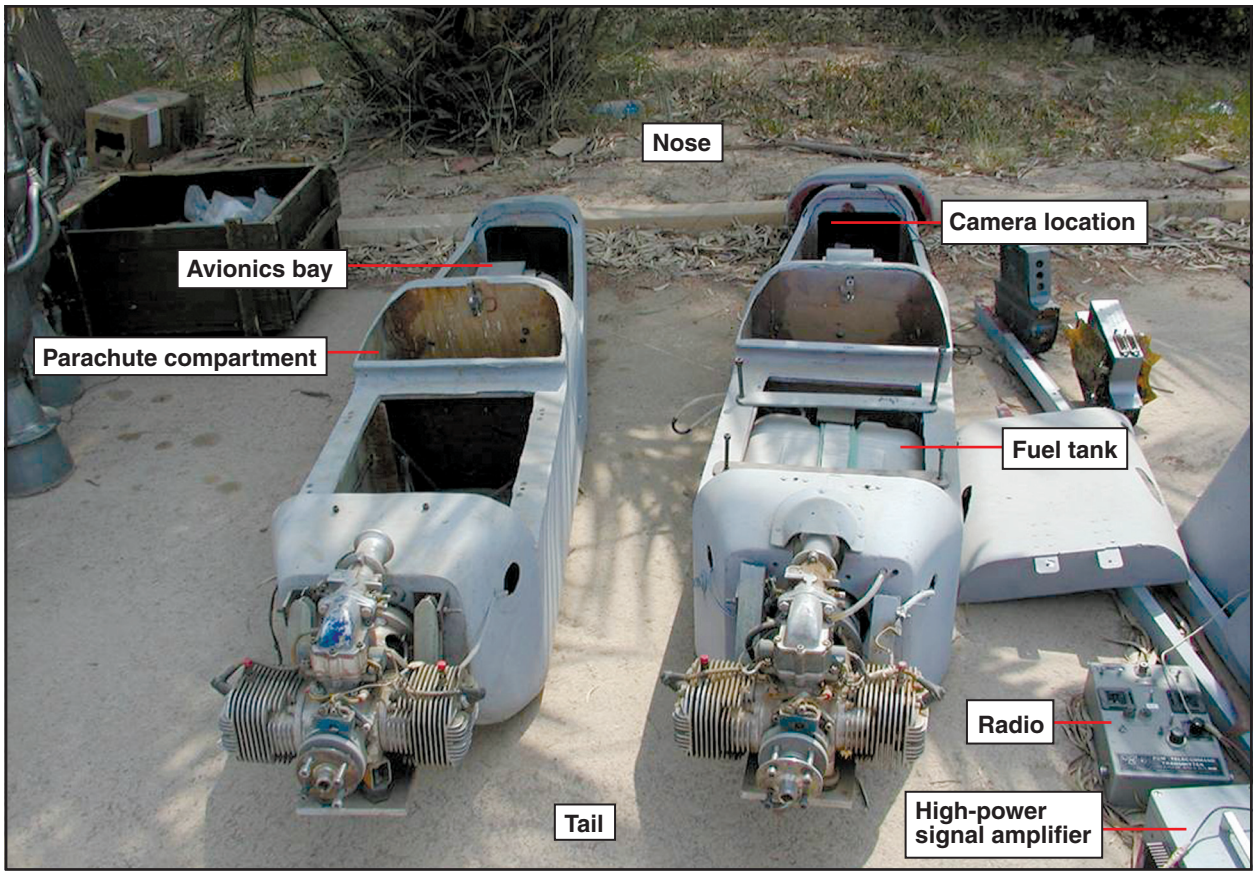

Figure 24. *Al Musayara-20 components.*

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, pos-

sibly 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.

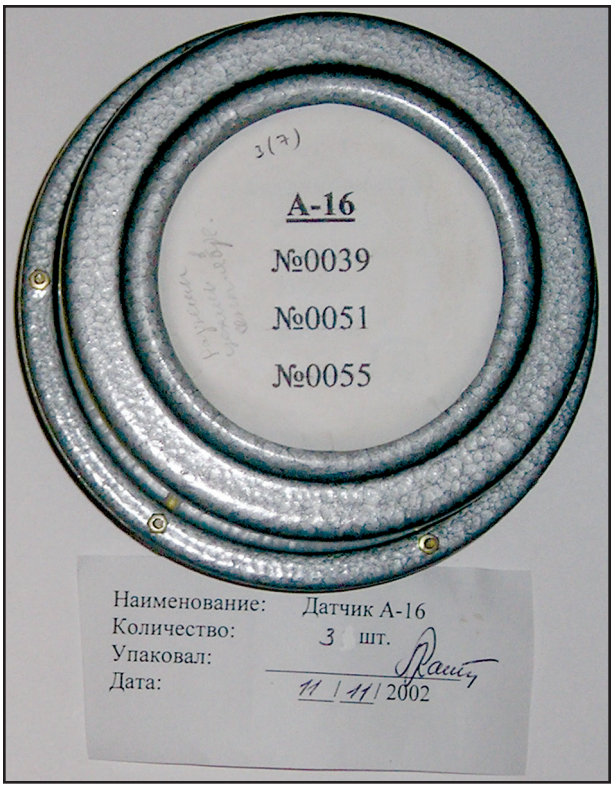

Figure 27. *A-16 shipping container.*

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

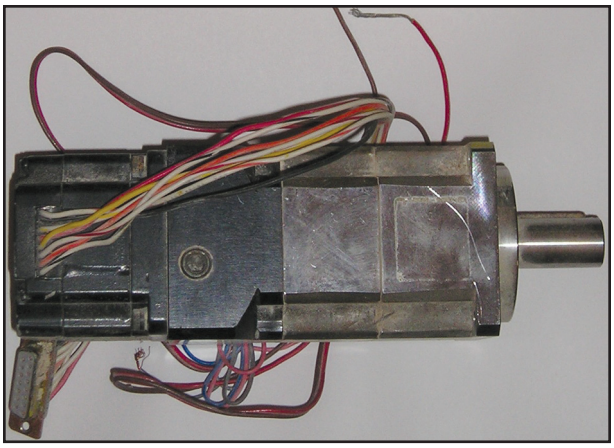

Figure 29. *Actuator stepper motor.*

- 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, was 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/m³ (1.6 g/cc) are only useful for nonnuclear or nonrocket application. Densities above 1,700 kg/m³ are useful for missiles and above 1,800 kg/m³ 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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