

Missile Defence Myopia: Lessons from the Iraq War

Dennis M. Gormley

Strategists have already seized upon the US military's 21-day march to Baghdad as a vindication of US Secretary of Defense Donald Rumsfeld's determination to transform the US military into a tightly integrated force capable of quickly and decisively defeating any conceivable adversary.¹ American air, sea and land forces demonstrated an extraordinary capacity to deliver offensive military power in a highly orchestrated way. The promise of Network Centric Warfare – the Pentagon's appellation for a robustly networked joint force capable of sharing and acting upon a common picture of both friendly and enemy activities – became evident when offensive firepower was brought to bear simultaneously throughout the theatre of operations.

Yet the Rumsfeld-led transformation was not nearly as impressive on the defensive side of American military performance. Admittedly, the war's greatly anticipated engagement between Iraqi ballistic missiles and America's improved *Patriot* missile defences went decidedly in America's favour: all nine of Iraq's most threatening missile launches were successfully intercepted and destroyed. But American and Kuwaiti missile defences and warning systems apparently failed to detect or intercept four of five Iraqi low-flying cruise missiles and there is no public evidence that *Patriot* was involved in one way or the other.² One of the cruise missiles came perilously close to a US Marine encampment on the war's first day. Furthermore, at least two Iraqi ultralight aircraft – which were feared capable of carrying chemical or biological agents – were detected only after flying over thousands of US troops, equipment and command facilities prior to the unit's advance on Baghdad.³ Iraq's use of low-flying cruise missiles and slow-flying air vehicles also contributed to the *Patriot's* unfortunate series of friendly fire incidents, two of which led to the loss of two aircraft and the deaths of three crew members.

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In a practical sense, the United States fielded only half a missile defence system, capable of handling but one dimension of the missile threat.

To many observers, asking missile defences to defend against low-flying cruise missiles and small manned or unmanned air vehicles must seem like moving the goalposts: with every new war, missile defences are called on to perform missions that appear to be ahead of what the technology can provide.⁴ But the truth is that awareness of the shortcomings of cruise missile defence and steps needed to rectify them date back nearly a decade. The Pentagon's own Defense Science Board conducted at least two detailed reviews and offered recommendations for improvements during the 1990s, while the Congress fashioned the 'Cruise Missile Defense Initiative' in its National Defense Authorization Act of Fiscal Year 1996. A call for greatly improved cruise missile defences to respond to an earlier-than-expected emergence of the cruise missile threat also made it into the Pentagon's *Defense Planning Guidance* in 1998.⁵ And in a report issued prior to *Operation Iraqi Freedom*, the Senate Armed Services Committee stated that the Pentagon's 'longstanding' combat identification and friendly-force tracking weaknesses, which surely contributed to the *Patriot's* friendly fire incidents, were not being rectified 'in the most expeditious manner'.⁶

Sadly, then, the poor performance of missile defences against cruise missiles, including the related problem of friendly-fire casualties, should have come as no big surprise. America's adversaries could draw important lessons from the performance of US missile defences against Iraq. The chief-of-staff of the 32nd Army Air and Missile Defense Command told the *New York Times* that 'this was a glimpse of future threats. It is a poor man's air force. A thinking enemy will use uncommon means such as cruise missiles and unmanned aerial vehicles on multiple fronts'.⁷ Although such worries were already in evidence prior to the war with Iraq, missile defence planners should anticipate an acceleration of interest in acquiring cruise missiles for at least two reasons.⁸ First, countries wishing to deter US military interventions were unlikely to invest heavily in cruise missiles for land attack until American missile defences performed decisively better against ballistic missiles than they did during the 1991 Gulf War. *Patriot's* success against Iraq's ballistic missiles in 2003 coupled with problems coping with cruise missile attacks increases the incentive for the United States' potential adversaries to acquire cruise missiles. Second, they are likely to see the operational advantages of combining ballistic and cruise missile launches to maximise the probability of penetrating even the best American missile defences. Converting small airplanes or UAVs into weapons-carrying 'missiles' offers a particularly attractive 'poor man's' option. When these, in large

numbers, are combined with more expensive and sophisticated ballistic and cruise missiles, they could have a distinct advantage over even layered defences.

Given the high stakes involved in facing an adversary with such offensive missiles armed with weapons of mass destruction (WMD) – most notably nuclear or biological weapons – America has no choice but to rectify the disparity in investments and bureaucratic attention between its ballistic and cruise missile defence programmes. Critical challenges face both missile defence planners and officials charged with missile non-proliferation policy.

Scoring ballistic missile defence

The Iraq War demonstrated positive returns on a \$3 billion programme to upgrade *Patriot* since its abysmal performance during the 1991 Gulf War, when the US Army rushed a modified version into combat. Its major limitation came from a proximity fuse that failed to detonate the fragmentation warhead close enough to destroy the missile warhead. Even when it did hit the intended target, it merely knocked the missile off course – and potentially towards urban centres or troop concentrations. A US Government Accounting Office report estimated that only 9% of the *Patriot* Advanced Capability-2 (PAC-2) interceptors actually hit their targets during the 1991 Gulf War, while Israeli authorities reported that *Patriot* succeeded in intercepting no more than one of the 39 Iraqi *Scuds* launched at Israel.⁹ This time around, upgraded PAC-2 missiles, together with roughly 50 of the latest *Patriot* interceptors, the PAC-3, were deployed. Army officials report that Iraq launched 19 ballistic missiles at coalition targets in Kuwait and Iraq, only nine of which proved to threaten potential targets. *Patriot* batteries successfully intercepted all nine of the most threatening missiles. Ten other non-threatening missiles, most of which may have been hastily aimed because the Iraqis feared coalition counter-fire, were allowed to land harmlessly in the desert or in Gulf waters.¹⁰

Patriot batteries were deployed in Kuwait, Qatar, Bahrain, Saudi Arabia, Israel and Turkey, the last under NATO control. Instead of remaining in fixed positions throughout the war, some Kuwaiti-based batteries moved with coalition ground forces towards Baghdad to furnish local-area protection. And rather than depending on just the space-based Defense Support Programme for warning information on launch detection, *Patriot* units were furnished with early warning information from two dedicated sources: an *Aegis* cruiser equipped with a *SPY* phased array radar deployed in the Persian Gulf, and a regionally deployed *Cobra Judy* ship-based radar system normally used to monitor missile tests.¹¹

America's decade-long investment in upgrading *Patriot's* performance has led to overall communications and command-and-control improvements that yield a seven-fold increase in the area each *Patriot* battery can protect. Of course, theoretical area protection is only useful to the extent *Patriot's* missile interceptors actually perform as expected. In *Operation Iraqi Freedom*, some missile defence batteries carried as many as three different interceptors – all developed since the 1991 Gulf War. According to an Army official, the *Patriot's* radar evaluates the incoming target's characteristics and automatically selects the best interceptor to engage it.¹² The first and most prominently used interceptor was the PAC-2 Guidance Enhanced Missile (GEM). Designed to rectify the intercept limitations of the PAC-2, the PAC-2 GEM features an altered fragmentation pattern in its high-explosive warhead together with modified electronics that enhance the probability of an explosive impact near the target missile's nose cone. A second set of improvements came with the introduction of the PAC-2 GEM-Plus, which includes an improved fuse and a missile sensor that enables the detection and engagement of smaller targets, presumably including cruise missiles. The third and most operationally tenuous of *Patriot's* upgrades is the entirely new PAC-3. Still in operational testing in early 2003, it appears that the entire US inventory of 50 PAC-3 interceptors was rushed into the region. The PAC-3 features controversial hit-to-kill technology, whereby the interceptor destroys the target, including any chemical and biological agents, by kinetic impact without a high-explosive warhead. Because the PAC-3 is considerably smaller than the PAC-2 (roughly a quarter to a third of PAC-2's weight), each *Patriot* launch canister can carry four PAC-3s compared with one PAC-2 GEM or GEM-Plus. Yet PAC-3's improved capabilities carry a hefty price tag: each four-missile canister costs \$12–15 million, or close to \$3.4m per missile compared with the original PAC-2's unit cost of \$700,000.¹³

Beyond cost is the question of whether the PAC-3 has been tested with enough operational realism to warrant confidence about its prospective performance in battle. The PAC-3 performed well (in fact, missing only one target) during a developmental sequence of 11 tests, but this was only against ballistic missiles or target drones flying predictable trajectories. In more recent operational testing, when a higher degree of battlefield realism was introduced, only three of seven targets were destroyed. Most importantly, to date, none of the PAC-3's tests has featured a ballistic missile target similar to the ones that proved so difficult to intercept in 1991 Gulf War. In order to extend their range, the Iraqis clumsily modified Soviet-furnished *Scud* missiles in the late 1980s. When they were launched in 1991, these longer-range *Scuds* encountered

severe aerodynamic stresses, which caused many of them to break up or flutter wildly, making them difficult to engage.¹⁴

During the war with Iraq, *Patriot* units were not tested against faster and more challenging *Scud* variants. American and British intelligence presumed that about 25 existed in Iraq's arsenal. Instead, Iraq used *al-Samoud-2* and *Ababil-100* ballistic missiles, which, given their range of, at most, 150km, are slower and easier to intercept. That said, a senior US army official noted that shorter-range missiles leave less time for defenders to respond to launches.¹⁵ Moreover, *al-Samoud* and *Ababil* missiles are much more accurate than *Scuds*. Even armed with only high-explosive warheads, rather than chemical or biological payloads, they represented a much greater threat to coalition forces. For example, according to the Army's post-event analysis, a *Patriot* missile intercepted an *Ababil-100* only three kilometres before it would have struck the coalition's main command centre at Camp Doha in Kuwait.¹⁶

More often than not, *Patriot* batteries employed the PAC-2 GEM interceptor to engage Iraqi ballistic missiles. Using PAC-2 GEMs, Kuwaiti-manned batteries were credited with shooting down two of the nine intercepted missiles. American-manned batteries successfully engaged the other seven Iraqi missiles, five with PAC-2 GEM interceptors and two with the new PAC-3 hit-to-kill interceptor.¹⁷ All missile batteries practiced the standard targeting doctrine of sequentially expending two missiles per target – and occasionally more, when it was determined necessary – in order to increase the probability of intercept. According to Army analysis, however, most intercepts came from the first missile fired.¹⁸ To avoid inflated claims of success such as those that followed the 1991 Gulf War, Army officials this time based their reports on electronic tapes of missile engagements and examinations of the remains of intercepted missiles found in the desert.¹⁹

While *Patriot* batteries performed well in their principal task, there were an extraordinarily high number of false alarms, despite the availability of both space-based and off-shore ballistic missile warning radars. Because military officials had to assume that Iraqi missiles might be carrying chemical or biological payloads, they erred on the side of caution, which caused alerted ground units to don chemical suits and gas masks in 37°C-plus heat. The repeated false alarms had such a debilitating effect on military performance that it led US and British on-the-ground commanders, worried about the pace of the ground advance towards Baghdad, to request that such alerts occur only when positive

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evidence of a missile launch was obtained. But in light of the risks of just one chemically armed missile getting through, senior military officials continued to practice a risk-averse warning policy.²⁰ Without greatly improved broad-area detection and tracking of cruise missiles and UAVs, the false-alarm rate will have even more deleterious effects in the future. Cruise missile launch signatures, unlike those for ballistic missiles, are too faint for confident launch detection by space-based and even most airborne sensors. Given that cruise missiles are substantially more effective than ballistic missiles in delivering chemical or biological weapons (conservatively, enlarging the lethal area for biological attack by at least ten times), military decision-makers are likely to be even more risk-averse for fear of the consequences.²¹

Success is relative

If *Patriot* missile batteries and other warning systems shone against ballistic missiles, they performed dimly against Iraq's improvised use of anti-ship cruise missiles and low-flying aircraft. In all, the Iraqis fired five Chinese-made HY-2 *Seersucker* (a NATO appellation) missiles, each of which can carry a payload of 500kg to a range of around 100km, flying a terrain-hugging profile to avoid radar detection. *Seersuckers* are designed for use against ships at sea, but can be employed – if far less effectively – over land, and especially flat desert terrain, to attack large targets that afford enough contrast for their primitive radar guidance systems to detect. The Interim Report of Dr David Kay, however, indicates that before the war the Iraqis had modified ten *Seersuckers* to permit them to be employed over land and to fly to a range of 150–180km.²² No matter which model was used, the Iraqis nearly achieved tactical success when, on the first day of the war, a *Seersucker* came undetected within one kilometre of striking Camp Commando, the US Marine Corps headquarters in Kuwait. Another hit just outside a large Kuwaiti shopping mall later in the war.

Although Army officials were quick to point out that each and every Iraqi ballistic missile that threatened coalition objectives was successfully engaged, they didn't explain how Iraqi cruise missiles managed to come so close to both a military and civilian target undetected. An industry official claimed that no *Patriot* assets were assigned in the area in which the mall was located, and that if there had been radars and interceptors in the area they could have engaged such low-flying threats.²³ While the *Patriot* system in theory is capable of engaging low-flying cruise missiles, in practice the *Patriot's* ground-based radar probably would not detect such low-flying missiles unless furnished with advanced warning information provided by an airborne radar. Many ground-based radars supporting today's air-defence missiles reduce the amount of ground

clutter by tilting the search beam back about three degrees, effectively lifting it above the ground. This increases the chances that a low-flying cruise missile will go undetected. Moreover, whereas airborne radar systems (like the US Air Force's Airborne Warning and Control System, or AWACS) can see several hundreds of kilometres, the earth's curvature means that the *Patriot's* ground-based radar, in trying to detect a cruise missile flying at a 50-metre altitude, might first see it only when it has closed to some 35km or less. This would leave roughly two-and-a-half minutes to react to an incoming *Seersucker*. Curiously, the Kay Report's claim that one *Seersucker* was shot down does not explain by what means. In any event, *Patriot's* inherent limitations against such threats were recognised after the war when William Schneider, chairman of the Pentagon's advisory Defense Science Board, called for integrating airborne sensors like AWACS with *Patriot* to improve chances of intercepting low-flying cruise missiles.²⁴

Equally telling were the two Iraqi ultralight aircraft that went undetected until they were directly over a large US Army forward encampment south of Baghdad on 28 March. A day after the incident, Central Command officials were still telling reporters that the Iraqis were incapable of flying aircraft because their airfields were being kept closed and carefully monitored.²⁵ However, ultralights and other kit-built aircraft do not require airfields to take off and land. Moreover, sophisticated airborne surveillance aircraft like AWACS and the US Air Force Joint Surveillance Target Attack Radar System (JSTARS) are unable to detect them because their radars screen out slow-flying targets on or near the ground to ensure that their data processing and display systems are not overburdened.²⁶

*Two Iraqi
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It remains unclear whether a *Patriot* battery was covering the forward US Army encampment, though it seems likely since missile defence units were deployed in Iraq in part to furnish protection for such units. Onsite reporting indicates that anti-aircraft units, consisting of *Linebacker* (*Bradley* fighting vehicles armed with *Stinger* anti-aircraft missiles) and *Avenger* systems (Humvees mounted with *Stingers*), received a mid-afternoon report on the ultralights and oriented their fire units to prepare to engage the small aircraft. Unit members visually spotted the ultralights flying at about 270 metres above the ground roughly at the speed of a helicopter. But the Iraqi aircraft had departed the area by the time higher command had approved their firing on such targets, as required by local rules of engagement. The enormously cluttered friendly air environment probably accounts for the lengthy decision process. Local air defence

officers admitted that it was difficult to distinguish the ultralights from the huge number of returning US helicopters and fixed-wing aircraft on their radar screens.²⁷

Unintended consequences

During the 1991 Gulf War, *Patriot* batteries had a relatively easy task when they were confined to detecting the comparatively steep trajectories of ballistic missiles. Coalition air forces had rapidly eliminated the Iraqi air force and no cruise missile, small airplane, or UAV threats existed. Thus, coalition defenders could afford to establish highly restrictive rules of engagement, which effectively shut down *Patriot* batteries against everything but the ballistic missile threat. This, in turn, prevented friendly fire accidents from occurring. But because a cruise missile and UAV threat had materialised by the time of the second Gulf War, comparably narrow rules of engagement were apparently not implemented.²⁸ As a consequence, an American *Patriot* unit inadvertently shot down a British *Tornado* fighter three days into the war, killing two crew members. The next day, to avoid the same fate, a US Air Force F-16 destroyed a *Patriot* ground-based radar after it mistakenly 'painted' the friendly aircraft. In spite of efforts to tailor *Patriot* rules of engagement after these incidents, yet another friendly aircraft, a US Navy F/A-18, was shot down and its pilot killed on 2 April.²⁹

Subsequent press interviews with industry and military officials, and reporting on the formal post-war investigations, focused specifically on the responsible *Patriot* batteries and friendly aircraft and on possible flaws in positive electronic means and procedural tactics (such as using protected engagement zones for returning friendly aircraft) associated with combat identification. Indeed, a malfunctioning identification electronic warning beacon on the British *Tornado*, the *Patriot* crew's decision to place its radar on automatic owing to heavy local fire, and heavy electronic interference due to the positioning of two *Patriot* radars too close to each other, have been cited as possible explanations for the respective friendly fire incidents.³⁰ Yet while the formal investigation was still underway, the US Army's Center for Lessons Learned noted in its own evaluation that positive electronic means of identifying airborne objects have 'low reliability'. In fact, based on military exercises conducted in 1993, a 1996 National Research Council study reported that 'attempts to coordinate air and [surface-to-air missile] intercepts in the same airspace led to unacceptably high levels of [simulated] fratricide'.³¹

Regardless of whether combat identification measures (such as acoustic signatures of friendly aircraft or IFF transponders) or protected engagement zones are used, the levels of simulated friendly fire incidents

Threat and response timeline

Date	Threat(s) – Real or Mistaken	Apparent Target(s)	Response
20 March	1 cruise missile	Marine Camp Commando	No detection indicated, nor missile interception attempted.
20 March	3 ballistic missiles	101 st Airborne Division; Camp Doha; and Camp Udari	US <i>Patriot</i> batteries intercepted all 3 threatening missiles.
21 March	1 ballistic missile	Ali Al Salem air base	Kuwaiti <i>Patriot</i> battery intercepted 1 threatening missile, while 2 others were allowed to land in the desert or Gulf.
23 March	British Tornado GR-4	Somewhere in northern Kuwait	US <i>Patriot</i> PAC-2 battery misidentified friendly aircraft as a missile threat and destroyed the aircraft, killing two pilots.
24 March	1 ballistic missile	US troops in Kuwait	A US <i>Patriot</i> battery apparently intercepted 1 threatening missile, while another non-threatening missile landed in the desert.
24 March	US F-16 CJ	<i>Patriot</i> battery forward-deployed to protect 3 rd Infantry Division	Mistaking the F-16 for a missile threat, the <i>Patriot's</i> radar 'painted' the F-16, which in turn fired on the radar, damaging it. The <i>Patriot</i> battery, reportedly, was operating on automatic.
25 March	1 ballistic missile	Somewhere in Kuwait	A Kuwaiti <i>Patriot</i> battery intercepted the threatening missile.
26 March	1 ballistic missile	Somewhere in Kuwait	A Kuwaiti <i>Patriot</i> battery intercepted the threatening missile.

Date	Threat(s) – Real or Mistaken	Apparent Target(s)	Response
27 March	1 ballistic missile	Camp Doha	A US <i>Patriot</i> battery intercepted an <i>Ababil</i> 100 missile on course for the allied command center.
28 March	2 cruise missiles	First aimed apparently at Kuwait's naval port; second hit close to nearby shopping mall	Press reports indicate no detection and no interception. Kay Report claims one missile shot down but no date given. Shoot down could have occurred on 31 March.*
28 March	2 manned ultralight reconnaissance aircraft	US Army forward encampment south of Baghdad	No detection until 2 penetrating aircraft were directly over encampment. No interception attempted due to delay in execution authority.
29 March	1 ballistic missile	Somewhere in Kuwait	This reported intercept by a Kuwaiti <i>Patriot</i> battery may be apocryphal. US Army officials reported that Kuwaiti <i>Patriot</i> batteries successfully engaged only 3 missiles.
31 March	2 cruise missiles	Allied forces at Umm Qasr; another at forces at Safwan	No evidence of detection, or attempt at interception, but neither missile threatened targets.
1 April	1 ballistic missile	Apparently allied forces near Najaf	A US <i>Patriot</i> battery intercepted the threatening missile with a PAC-3 interceptor.
2 April	US F/A-18C	Near Karbala	A US <i>Patriot</i> battery misidentified the F/A-18 as a threatening missile and destroyed the aircraft, killing its one pilot.

Sources: Author's compilation based on Center for Defense Information, at <http://www.cdi.org/document/search/displaydoc.cfm?DocumentID=1001&StartRow=1&ListRows=10>; Michael R. Gordon, 'A Poor Man's Air Force', *New York Times*, 19 June 2003, p.1; Sean D. Naylor, 'Iraqi ultralights spotted over U.S. Troops', *Army Times*, 29 March 2003, at <http://209.157.64.200/focus/f-news/879398/posts> and Interim Report of the Iraqi Survey Group (Kay Report), at http://www.cia.gov/cia/publicaffairs/speeches/2003/david_kay_10022003.html.

*The Kay Report indicates that 10 modified (from anti-ship to land attack) HY-2 *Seersucker* missiles were delivered to the Iraqi military before the war, and of the two used during the war, one was shot down though by what means is not stated. After the war, 33 *Seersucker* missiles were found intact on the al-Faw peninsula, suggesting that perhaps both anti-ship and land-attack versions were used to account for the total of five reported used during the war.

have been disconcertingly high, often producing friendly-aircraft attrition levels of 10–20% or more.³² Technical or procedural flaws do not completely explain the longstanding systemic weaknesses of American air combat identification. While establishing communications between AWACS and *Patriot* batteries would be a step in the right direction, for instance, problems would remain severe in the early stages of any conflict when only minimal surveillance and battle management and control systems would likely be in place and coordination among service air fleets and coalition partners probably would not have gelled. As the cruise missile and UAV threat grows, today's fratricide and missile defence challenges could become tomorrow's nightmare.

A glimpse of future threats

The nature of future air campaigns is far less likely to involve air-to-air combat than the enemy's use of both ballistic and cruise missiles against air defences. While the enemy's aircraft must operate from highly vulnerable airfields, which are high-priority targets in the early hours of any initial air campaign, ballistic and cruise missiles can be launched from mobile launchers. These have proven devilishly difficult to find and successfully destroy in past military campaigns. During the 1991 Gulf War, the coalition was unable to destroy even one Iraqi *Scud* launcher, and while counterforce-targeting capabilities have improved somewhat since 1991, the advent of ground-launched cruise missiles will tax them further. Pre-launch attack is obviously preferable against WMD-armed missiles, but pre-launch detection of cruise missiles is especially problematic because cruise missile launchers are smaller than ballistic missile launchers and more closely resemble other civilian and military vehicles. This could mean a doubling of the 'look-alike' or 'confuser' population, which places the burden of distinguishing real from false

targets on airborne sensors.³³ And, as noted before, post-launch detection of cruise missiles will be highly doubtful due to their faint launch signatures. Although it is premature to draw any conclusions about the record of counterforce attacks on Iraqi missile launchers during the second Gulf War, the Iraqis did manage to continue firing both ballistic and cruise missiles throughout the brief campaign, and 33 *Seersucker* missiles, along with two launchers, were found intact on the al-Faw peninsula after the war ended.³⁴

In light of Iraq's use of surplus *Seersuckers* during the war, any projection of the future cruise missile threat necessarily ought to begin with a closer look at anti-ship cruise missiles. Whether or not to allay the fear of Kuwaiti citizens, who experienced several unnerving if ultimately harmless *Seersucker* attacks during the recent war, coalition military officials severely misrepresented the potential capability of these missiles. 'The *Seersucker* is much, much smaller than a *Scud* and we don't think it can be converted to carry any significant NBC [nuclear, biological or chemical] payload', said one coalition office after *Seersuckers* were launched against targets in Kuwait.³⁵ In fact, the *Seersucker's* smaller size is arguably an operational advantage, and certainly not a disadvantage. The *Seersucker* can be transformed into a comparably long-range missile without becoming nearly as heavy and difficult to support as the *al-Hussein*. Furthermore, each missile delivers a payload of 500kg. The *Seersucker* is a decidedly more suitable platform for delivering biological and chemical payloads than a *Scud* or *al-Hussein* in that the cruise missile's steady horizontal flight pattern permits the release and spraying of agent at right angles to the wind direction and upwind of the target area, greatly increasing dissemination efficiency compared with a ballistic missile.³⁶

States may wish to achieve significantly greater lethal effects from their surplus inventories of *Seersuckers* by converting them into genuine land-attack cruise missiles. According to the Kay Report, this seems to be precisely what Iraq did to at least ten of its surplus *Seersuckers*. Launched over water and flying low, anti-ship cruise missiles like the *Seersucker* have a relatively easy task: using a simple autopilot for navigation, they employ a terminal radar guidance system to seek out a large metal object (ship). Used over the desert, however, such missiles have more difficulty in hitting their intended targets because such targets furnish less contrast than a ship at sea.³⁷ Land-attack cruise missiles generally must navigate more variegated terrain than anti-ship cruise missiles (or such missiles launched over desert terrain) before they reach their intended targets, while flying low to avoid detection.

Conversion is nothing new. The US Navy has transformed the ubiquitous *Harpoon* anti-ship cruise missile (exported to 24 nations) into

the Stand-off Land-Attack Missile (SLAM/AGM-84E). Russia's export family of anti-ship cruise missiles, called *Klub*, has a dual-mode feature on at least one version – the jointly produced Russian-Indian *Brahmos* cruise missile – that permits attacks against ships at sea and targets over land.³⁸ Yet North Korea and Iran could convert their existing inventories of *Seersucker* missiles to much more dangerous effect. Modern anti-ship cruise missiles like *Harpoon* and the French *Exocet* are considerably smaller in overall size and space than the older *Seersucker*. They are densely packed with electronics, leaving little room for the kinds of changes required to both convert an anti-ship missile into a land-attack one and increase the missile's range.³⁹ The HY-2 *Seersucker's* roominess and simplicity of design make it easier to convert to land-attack roles than any of the more modern anti-ship designs.

Conversion is technologically much easier to accomplish than it was a decade ago. Then, countries like the United States and Russia depended on tightly controlled guidance systems such as Terrain Contour Matching (TERCOM), which match highly classified imagery from satellites with radar returns from a miniature radar in the missile's nose to guide the system to within tens of metres of the target. Now, navigation for land-attack cruise missiles requires only relatively cheap and widely available inertial navigation systems integrated with Global Positioning System (GPS) receivers.⁴⁰

Two main barriers still stand in the way of converting surplus *Seersuckers* or other members of the HY anti-ship missile family. The first and most formidable is obtaining a modern land-attack navigation system. Although the already noted component technologies are readily available 'off the shelf', it is not easy to integrate individually complex electronic subsystems into a working whole that achieves repeatable results demanded of a precision delivery system. Yet there are shortcuts that make the job simpler. The most attractive is to acquire a commercially available UAV flight management system designed to convert a manned aircraft into a fully autonomous UAV. Several small aerospace companies have emerged since the advent of GPS to sell fully integrated flight management systems along with an array of system integration services that greatly ease the conversion task. The second and less challenging barrier is that of incorporating a suitable jet engine to replace the *Seersucker's* liquid-fuelled rocket engine. There is a large pool of export-unrestricted turbojet engines in the civilian and military marketplace from Canadian, European, Japanese, American and other international manufacturers from which to draw. With space liberated from replacing the *Seersucker's* autopilot and radar guidance with a modern (and thus much smaller) navigation system, a converted missile

could achieve a range of at least 500km for a payload of 500kg. That range could be extended if the payload was reduced in exchange for added fuel, or if the airframe was extended to allow for more fuel.⁴¹ The Kay Report indicates that the Iraqis were working on a more ambitious conversion of the *Seersucker* than the model used in the war, involving the incorporation of a Russian turbine engine designed to fly the missile to a range of 1,000km. If Iraq had managed to perfect their converted *Seersuckers'* land-navigation system, their attacks against Kuwait could have achieved militarily and politically significant damage.

A truly 'poor man's air force' of cruise missiles would best be achieved by converting simple, cheap kit airplanes into weapons-carrying vehicles. Larger than the ultralights used by Iraq, kit airplane conversion would involve substantially less cost, less significant engineering prowess, and fewer steps – and thus less chance of failure – than either converting anti-ship cruise missiles or small reconnaissance or target drones into land-attack systems. From a worldwide list of manufacturers, an adversary could choose from among nearly 500 well-tested designs, many with ranges to 1,000km, payloads of 200kg, 100-metre take-off distances from unhardened fields and cruise speeds of 120 knots. The average cost for the kit and engine combined is around \$25,000. As with converting an anti-ship cruise missile, the major technical hurdle lies in building and integrating a flight management system, along with servo controls and actuators, in order to fly the system autonomously over the desired range.⁴² But instead of wrestling with this difficult challenge alone, a rogue state or terrorist group could turn to the new manufacturers of flight management systems and related support services to produce an autonomous UAV. At present, no export controls govern foreign sales, nor, of course, domestic US transactions for these services. Outside flight management assistance would add around \$35,000 to the cost of producing each vehicle – meaning a per-unit cost of roughly \$60,000 – but would greatly save on the overall time to produce a militarily useful number of converted airplanes.⁴³ Such a delivery system would have sufficient payload weight and space to carry a sprayer system that could deliver a biological or chemical agent. A payload of gasoline could produce significant damage to many soft civilian and military targets, as this common fuel, when mixed with air, releases 15 times the energy as an equal weight of TNT.⁴⁴

The most worrisome scenario is one in which large numbers of cheap cruise missiles, combined with smaller numbers of much more sophisticated and stealthy cruise missiles, confront missile defence systems expected to take on both low-flying cruise and high-angle ballistic missile threats. It still remains to be seen how effective the

principal missile non-proliferation mechanism – the Missile Technology Control Regime (MTCR) – will prove to be in staunching the spread of highly advanced cruise missiles. Britain and France’s decision in the late 1990s to sell the United Arab Emirates their jointly produced, stealthy cruise missile, called the *Black Shaheen*, in spite of Washington’s protestations that the missile was subject to the MTCR’s highest degree of controls, set an unwelcome precedent. More problematic states like Russia and China may wish to follow suit by selling their own advanced cruise missiles to states outside the MTCR’s membership.⁴⁵ At the very least, a toxic mix of low- and high-end cruise missiles together with ballistic missiles could produce unacceptable levels of friendly fire casualties to combat aircraft. More dire is the prospect that high-cost missile defence inventories will be roundly insufficient to cope with low-cost offensive missile attacks. Given that the guidance upgrade alone on the PAC-2 GEM-Plus costs \$400,000 per missile, and that each new PAC-3 interceptor costs \$3.5m, it becomes clear that a flock of cruise missiles several orders of magnitude cheaper could saturate most economically feasible missile defence architectures.⁴⁶

American missile-defence planners cannot focus solely on regional contingencies against state actors and military force-projection requirements. Terrorist use of UAVs and cruise missiles against overseas military assets should receive serious attention.⁴⁷ To take just one example, the US Navy must begin to examine force-protection measures that deal with slow-flying UAV threats to ships in port. Defending against cruise missiles is also a global counter-terrorism matter. Using converted *Seersuckers* to attack homeland targets is also a conceivable future scenario. In the aftermath of the 11 September 2001 terrorist attacks, US decision-makers began to take the offshore cruise missile threat more seriously than ever before.⁴⁸ Even cruise missiles as large as the *Seersucker* can be hidden and launched from standard 12-metre shipping containers. Launched from just outside territorial waters, these missiles could strike many of the world’s large population and industrial centres. The latest US National Intelligence Estimate draws attention to this scenario, including its possible association with non-state actors.⁴⁹ Two former US National Security Council staff members recently highlighted such a scenario, noting that al-Qaeda is believed to possess 15 freighters.⁵⁰ Finally, airborne threats can emanate from inside as well as outside US territory. Small slow-flying airplanes can be launched from concealed land locations close to their intended targets just as Iraqi ultralights did.

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Making missile defence work

The increased saliency of the cruise missile and UAV threat means that highly restrictive rules of engagement that focus only on high-angle ballistic missiles to prevent friendly fire incidents can no longer compensate for the inadequate ability of American air defences to distinguish friendly aircraft from enemy cruise missiles. The inadequacy is attributable to the disparate data links and target-tracking techniques used by the military services. Substantial enhancements will require the

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merging of various service and Missile Defense Agency (MDA) battle management command, control and communications programmes to achieve connectivity across the services. The quest for such a joint approach, now known as the Single Integrated Air Picture (SIAP), was initiated as far back as 1969 to improve tactical air control. If SIAP were fully realised, it would afford users, including allies, the wherewithal to share multiple-aspect viewing of threats over a broad geographic region, greatly reducing gaps in coverage and widening the window within which to provide timely cues to air and missile defence weapons. Having one fully interoperable

view of the air picture would also accelerate decision-making on identifying friend from foe, limiting the incidence of air fratricide.

While improved tracking through SIAP interoperability makes sense, its effectiveness depends ultimately on better airborne sensors for detecting low- and slow-flying cruise missiles and UAVs. *Patriot* missile defence interceptors are theoretically capable of shooting down low-flying cruise missiles, but the horizon limits of their own ground-based radar means they must depend on a sensor deployed on an airplane or balloon to alert the fire battery in sufficient time to engage the incoming missile. The US Army is developing a surveillance and fire-control sensor carried by an aerostat (a blimp-like balloon flying at 4,570 metres). Called the Joint Land-Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS), the system has several shortcomings. While the US Navy has expressed some interest, JLENS remains essentially an Army programme. The time it would take to deploy such a system is prohibitively long; also, JLENS is sensitive to weather and cannot cope with terrain-masking challenges in areas with high terrain such as northeast Asia. Nevertheless, JLENS could complement higher-flying, faster-reacting, weather-insensitive aircraft like the US Air Force's next-generation wide-area surveillance and battle management platform – the Multi-Sensor Command and Control Aircraft (MC2A).

Intended to incorporate the functions of both the airborne and ground-based surveillance missions of today's AWACS and JSTARS, MC2A would include improved sensors to detect low-flying cruise missiles and furnish fire-control information to both airborne and ground-based interceptors. The challenge here is to take full advantage of such a capability by linking various Army and Navy missile defence systems into a new concept of operation known as air-directed surface-to-air missile (ADSAM). This concept would radically alter and dramatically improve the currently service-centric approach to controlling the fires of missile defence batteries, whereby each missile is guided to its target by its own horizon-limited radar. ADSAM would hand over fire-control responsibility to a centralised, elevated platform – namely, MC2A – so that the Army and Navy would depend on an Air Force system to execute their missile defence responsibilities.⁵¹ No longer limited by their ground-based radars, each Army and Navy missile defence interceptor would be capable of intercepting low-flying cruise missiles to their full range potential of 100–150km. Air-to-air missiles fired by Air Force fighters would also see their range extended to perhaps 60km. Unfortunately, MC2A will not be available until 2011 at the earliest, even if funding remains steady and technical challenges are suitably met. Should the cruise missile and UAV threat intensify more rapidly, it may become necessary to accelerate MC2A's development or incorporate ADSAM capabilities into existing service airborne platforms.

If the new threats posed by cruise missiles and other slow-moving aircraft are profound, the defensive benefits derived from ADSAM's revolutionary concept of operations are equally far-reaching. With increased interceptor range come multiple shot opportunities and greatly reduced leakage against large onslaughts of cruise missiles. High-quality fire-control sensors on a high-flying airborne platform mean that air fratricide could be significantly reduced, as potential targets, friend and foe alike, would be identified and tracked over great distances. Although ADSAM would not lessen the need to develop cheaper missile defence interceptors, the concept would make more efficient use of finite interceptor inventories since each battery would provide much greater coverage. Nevertheless, the prospect of large raids from a 'poor man's air force' underscores two additional priorities: driving down the cost of today's high-priced interceptors and modifying current and future airborne radars to permit them to track slow-flying targets in the 60–90 knot range.⁵²

The challenges and potential costs of defending the homeland against both offshore and domestic cruise missile threats are considerable.

The North American Aerospace Defense Command (NORAD) is currently studying the idea of an unmanned airship operating at an altitude of 21,000 metres and carrying sensors to monitor and detect offshore low-flying cruise missiles. Several such airships would be needed, along with fast-moving interceptors to cope with perceived threats. Perhaps 100 aerostats at an altitude of 5,000 metres could act as a complementary or alternative system of surveillance and fire control for an interceptor fleet. Other problems would still remain. Better methods are needed of providing warning information to the Coast Guard on potentially hostile ships embarking from ports of concern. Missile threat sensor data must be capable of distinguishing between friendly traffic and enemy threats prior to threat engagement. A sufficient national cruise missile defence requires improvements to respective service programmes, and ideally would involve implementing the SIAP programme. The question of affordability looms large. Even a limited defence against offshore cruise missiles would cost \$30–40bn. Finally, improvements are needed in defences against domestic-based threats. In the aftermath of 11 September NORAD had no internal air picture, nor were its radar assets linked with those of the Federal Aviation Administration (FAA), which controls internal US-air traffic. Progress towards making such linkages has occurred but major gaps remain, especially when dealing with the detection of low- and slow-flying air targets.⁵³ In sum, comprehensive defences against offshore cruise missiles and domestic terrorist attacks employing light aircraft will remain operationally, technically and financially problematic for at least the next decade.

Pressing missile defence challenges are the stuff of true military transformation. They require unprecedented service cooperation, disciplined civilian and military leadership, steady budgetary support from the Congress and perhaps even organisational changes in the way the Pentagon manages missile defence. The situation may be desperate, but it is not hopeless. Commenting on a 2001 counter-terrorism exercise in which a simulated cruise missile was launched from a merchant ship in the Gulf of Mexico, the NORAD test director said, 'we are naked ... [and] have no capacity to deal with that kind of problem'. As for implementing SIAP, however, he also observed that 'interoperability is achievable, if the leadership wants it to be achievable'.⁵⁴ Making combat identification a comprehensively joint endeavour has been stymied largely because the Pentagon's mechanisms for implementation do not have inter-service sweep. Annual action plans can only implore the services to action, not authorise funding and execution, which is the exclusive domain of each service.⁵⁵ Thus, SIAP implementation is far less a

matter of technology than bureaucratic politics. While stressing its concern about the growing cruise missile threat, the Bush administration has avoided any radical departure from business as usual in regard to the service-centric approach to cruise missile defence. True transformation may simply demand a single Pentagon agency to lead development of cruise missile defences, similar to the MDA, which manages all aspects of ballistic missile defence.

Non-proliferation policy helps, too

The MTCR – the only extant multilateral arrangement covering the transfer of missiles (ballistic and UAVs), related equipment, material and technology relevant to delivery of weapons of mass destruction (WMD) – is flawed but has frequently been effective. On one hand, it has achieved remarkable – and largely unsung – success in controlling the qualitative spread of ballistic missiles by curtailing the export of dual-use components, technologies and production capabilities relevant to making ballistic missiles. As a consequence of the MTCR, the spread of ballistic missiles to date has been limited largely to 50-year-old *Scud* technology. This achievement makes missile defences more practical, as they can exploit many of the weaknesses of this level of rudimentary missile technology. On the other hand, the MTCR has been too easy on cruise missile proliferation. For example, current MTCR coverage of flight management systems and technology (under Item 10, Category II) is too narrowly crafted to have any inhibiting effect on access to the technology required to convert anti-ship cruise missiles into more lethal land-attack drones.⁵⁶

The MTCR has been too easy on cruise missile proliferation

Policy affecting the pace and scope of cruise missile and UAV proliferation, however, received a palpable boost in potential effectiveness in late 2002. Diplomats from the 33 states party to the MTCR, while gathered in Warsaw, Poland in September for their annual plenary meeting, agreed on new language to tighten ground rules for defining the true range of cruise missiles and UAVs. This makes it more difficult for states to exploit the inherent range variability of these non-ballistic systems to justify the transfer of highly advanced cruise missiles and UAVs to potentially worrisome states. MTCR member states also took the first step toward addressing possible terrorist use of UAVs and cruise missiles by concluding the Warsaw meeting with a commitment to examine ways of limiting the risk that controlled items and their technologies could fall into the hands of terrorist groups and

individuals.⁵⁷ No more effective way of fulfilling this commitment exists than to close existing MTCR loopholes affecting the spread of new flight management technology. A sense of urgency in placing more effective controls on this technology appears to lie behind a January 2003 US 'antiterrorism' proposal to the Wassenaar Arrangement, a group of 33 co-founding nations that strives to achieve transparency and greater responsibility in transfers of conventional arms and dual-use goods and technologies (including UAVs). Expressing concern about the possible terrorist use of kit airplanes and other manned civil aircraft as makeshift UAVs, the US proposal seeks export control reviews and international notifications for all equipment, systems and specially designed components that would enable these airplanes to be converted into UAVs. However, because the Wassenaar Arrangement does not incorporate the MTCR's strong denial rules and no-undercut provisions, the MTCR membership should act quickly to improve its own controls on UAV flight management systems.⁵⁸

There are additional ways to make the MTCR a more effective instrument in controlling the pace and scope of cruise missile and UAV proliferation. These include more stringent restrictions on missiles with a given stealth capability; on certain countermeasure systems (such as towed decoys and terrain-bounce jammers specifically designed to match the delivery system they are aiding); and on jet engines, which are now exempted as being for manned aircraft but are nonetheless suitable for UAV/cruise missile use. It is equally important to preclude the erosion of existing MTCR controls. The Bush administration seems intent on liberalising standards covering both large UAVs (e.g., *Predator* and *Global Hawk*, for example) and missile defence interceptors (e.g., the *Arrow* system, which Israel wants to sell to India), arguing that the regime's provisions regarding export of these systems are inconsistent with the MTCR's original goal of arresting the spread of WMD delivery systems. Large reconnaissance UAVs are seen as capable of achieving great target discrimination, as opposed to mass destruction, while the spread of missile defences, particularly in the aftermath of withdrawal from the Anti-Ballistic Missile (ABM) Treaty, is something to be supported rather than constrained. But in the wrong hands, seemingly benign UAVs and missile defence interceptors are capable of delivering significant WMD payloads to great distances. A lack of care in dealing with non-proliferation mechanisms could also produce unwanted precedents for other states to act cavalierly. The administration should not undertake any radical departures from longstanding missile non-proliferation norms.⁵⁹

Heeding a serendipitous warning

Turning American missile defences into a tightly integrated and carefully orchestrated joint operation, capable of dealing with both ballistic and cruise missiles while avoiding air fratricide to the extent possible, remains a major challenge for the Rumsfeld-led military transformation drive. Too often, government decision-makers are beset by an overwhelming array of immediate tasks, causing them to fixate myopically on a few problems that do not always include those most deserving of their attention. It is vital that the problem of defending against non-ballistic missiles is no longer neglected in this way. States and terrorist groups wishing to acquire a 'poor man's air force' or even more advanced cruise missiles will not leave many fingerprints. Such development programmes, unlike ballistic missile ones, are far less susceptible to intelligence monitoring. But the second Gulf War has given top officials a rare glimpse of future threats. The lessons from Iraq should therefore be taken as a fortuitous wake-up call to embrace substantial military and diplomatic measures to cope with threat uncertainty. They should trigger a more aggressive approach to making missile defences work against a more plausible range of missile threats. Anything less would be irresponsible.

Acknowledgements

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Notes

- ¹ See, for example, Max Boot, 'The American Way of War', *Foreign Affairs*, vol. 82, no. 4, July/August 2003, pp. 41–58.
- ² The Interim progress report of the Iraqi Survey Group, delivered on 1 October 2003 by its head, Dr David Kay, is the only source suggesting that one Iraqi cruise missile was intercepted. All press and military commentary during the war indicated that not one Iraqi cruise missile was either detected or intercepted. For the Kay Report, see http://www.cia.gov/cia/public_affairs/speeches/2003/david_kay_10022003.html.
- ³ According to the US Federal Aviation Administration, an ultralight aircraft is defined as a single occupancy-only aircraft, used for sport or recreational purposes only. No airworthiness certificate is required. Moreover, a powered vehicle cannot be operated when it has an empty weight of 254 pounds (115kg) or more, a fuel capacity exceeding 5 US gallons (19 litres), or an air speed of more than 55 knots at full power in level flight. Whereas sport paragliders possess a steerable parachute canopy, ultralights have a fixed, stable wing frame. The two Iraqi ultralights spotted over US troops on 28 March possessed wings roughly 4.5–6m (15–20 feet) in length. See Sean D. Naylor, 'Iraqi ultralights spotted over U.S. troops', *Army Times*, 29 March 2003, at <http://209.157.64.200/focus/f-news/879398/posts>.
- ⁴ The author is grateful to Michael Krepon for this point.
- ⁵ These executive- and legislative-branch initiatives are documented in Dennis M. Gormley, *Dealing with the Threat of Cruise Missiles*, Adelphi Paper 339 (Oxford: Oxford University Press for the IISS, 2001), chapter 4. See also Dennis Gormley, 'Cruise Missile Threat Quietly Rises', *Defense News*, 27 March 1995, p. 27. See also *Cruise Missile Defense: Progress Made But Significant Challenges Remain*, GAO/NSIAD-99-68 (Washington, DC: USGAO, March 1999); and Dennis Gormley, 'Cruise Missile Threat Rises: US Navy, Army Lag in Defense Preparations', *Defense News*, 31 May 1999, p. 15.
- ⁶ David Ruppe, 'United States: Army Describes Patriot Friendly Fire Difficulties', *Global Security Newswire*, 29 July 2003, at http://www.nti.org/d_newswire/issues/2003/7/29/12s.html.
- ⁷ Michael R. Gordon, 'A Poor Man's Air Force', *New York Times*, 19 June 2003, p. 1.
- ⁸ For two recent appraisals of cruise missile proliferation, see Dennis M. Gormley, 'New Developments in Unmanned Air Vehicles and Land-attack Cruise Missiles', in *SIPRI Yearbook 2003* (Oxford: Oxford University Press for SIPRI, 2003), pp. 409–432 and Robert Wall, 'Land-Attack Cruise Missiles Seen as Growing Threat', *Aviation Week & Space Technology*, 25 August 2003, p. 38.
- ⁹ Andrea Stone, 'Friend or Foe to Allied Troops', *USA Today*, 14 April 2003, at http://www.usatoday.com/news/world/iraq/2003-04-14-patriot-missile_x.htm. US Army officials contend that *Patriot* units achieved a

- 70% rate of effectiveness in Saudi Arabia and 40% in Israel.
- ¹⁰ Various accounts exist of just how many Iraqi ballistic missiles were launched during the war. Pending the release of an official US Army report, the most authoritative account appears to be Kent Faulk, 'Patriots Intercepted 9 Iraqi Missiles, Says Project Head', *Birmingham News*, 22 August 2003, accessed via <http://www.lexus-nexus.com>.
- ¹¹ Gordon, 'A Poor Man's Air Force'.
- ¹² Elaine M. Grossman, 'Most Intercepts of Iraqi Rockets Were by Older Patriot Missiles', *Inside the Pentagon*, 24 April 2003, p. 1.
- ¹³ Andy Murray, 'Missile test', *Eagle-Tribune Publishing*, 23 March 2003, at http://www.eagletribune.com/news/stories/20030323/BU_001.htm. For further details on each *Patriot* interceptor, see the Federation of American Scientists' web site at <http://www.fas.org/spp/starwars/program/patriot.htm>.
- ¹⁴ Murray, 'Missile Test'.
- ¹⁵ The official was Lt. Gen. Joseph Cosumano, commander of the Army's Space and Missile Defense Command, as cited in Robert Wall, 'Dangerous Missile Mix Sparks Scrutiny', *Aviation Week & Space Technology*, 7 July 2003, pp. 47–48.
- ¹⁶ Gordon, 'A Poor Man's Air Force'.
- ¹⁷ Grossman, 'Most Intercepts of Iraqi Rockets'.
- ¹⁸ Wall, 'Dangerous Missile Mix Sparks Scrutiny'.
- ¹⁹ Bradley Graham, 'Radar Probed in Patriot Incidents', *Washington Post*, 8 May 2003, p. 21.
- ²⁰ 'U.S. Ground Forces in Iraq Wearied of Repeated False Missile Alarms', *Inside the Pentagon*, 26 June 2003, p. 1.
- ²¹ Gormley, *Dealing with the Threat of Cruise Missiles*, p. 9.
- ²² Kay Report.
- ²³ Wall, 'Dangerous Missile Mix Sparks Scrutiny'.
- ²⁴ *Ibid.* See also Marc Selliger, 'Patriot May Need Integration with AWACS, DOD Adviser Says', *Aerospace Daily*, 26 June 2003, on <http://www.lexus-nexus.com>.
- ²⁵ Details relating to the ultralight overflights are exclusively derived from Naylor, 'Iraqi ultralights spotted over U.S. troops', apparently the only onsite reporting that took place on this incident.
- ²⁶ Gormley, *Dealing with the Threat of Cruise Missiles*, p. 11.
- ²⁷ Army air defence and intelligence personnel were not completely surprised by the appearance of the Iraqi aircraft. In December 2002, months before the invasion, about six Iraqi ultralights were detected flying over US military camps in Kuwait. For reasons unspecified, US air defences failed to engage the aircraft. Air defence officers were told that the Iraqis attempted to procure at least 100 ultralights from an overseas company, but only around 50 were delivered by the war's outbreak. One Army intelligence officer believed the Iraqis might use ultralights for either strategic reconnaissance, spreading chemical or biological agents, or suicide attacks with high explosives. Despite this intelligence, pre-war threat briefings advised air defence units to expect the Iraqis to use paragliders (which use a parachute canopy) rather than fixed-wing ultralights. See Naylor, 'Iraqi ultralights spotted over U.S. troops'.
- ²⁸ Before the second Gulf War, senior Bush administration officials fostered the expectation that allied forces would face a threat from armed Iraqi UAVs, possibly carrying chemical or biological payloads. Anonymous officials leaked information suggesting that President Bush was concerned about the Iraqis sneaking a

small UAV into the United States for use against homeland targets. In the post-war search for Iraqi weapons of mass destruction, however, US forces recovered abandoned Iraqi UAVs that appear capable of performing only surveillance, not weapons-delivery, roles. The important point, however, is that prudent defence planning had to be predicated on the expectation that *Patriot* missile batteries might have to intercept both ballistic and UAV threats. For details, see David Rogers, 'Air Force Doubts Drone Threat: Report Says Bush Exaggerated Perils of Unmanned Iraqi Aircraft', *Wall Street Journal*, 10 September 2003.

²⁹ The senior air component representative to the ground headquarters in Iraq, Air Force Maj. Gen. Dan Leaf, noted that after the British *Tornado* was inadvertently shot down, a decision was taken to alter *Patriot*'s rules of engagement to make them 'more restrictive in certain modes'. Still, Leaf stated that they had to remain sufficiently permissive to permit *Patriot* to deal with the Iraqi missile threat. In the aftermath of the *Seersucker* cruise missile strike on the US Marines' Camp Commando on the war's first day, one might assume that the coalition could not afford to restrict *Patriot* only to fire against the steep trajectories of Iraqi ballistic missiles. See Elaine M. Grossman, 'Patriot May Mistake Aircraft for Missile in Combat's Electronic Glut', *Inside the Pentagon*, 24 April 2003, p. 1.

³⁰ For various explanations regarding the *Patriot* friendly-fire incidents, see Pamela Hess, 'The Pentagon's Fratricide Record', *United Press International*, 24 April 2003, at <http://www.lexus-nexus.com>; Grossman, *Ibid.*; Ruppe, 'United States: Army Describes Patriot Friendly Fire Difficulties'; Stone, 'Friend or foe to allied troops'; Graham, 'Radar Probed

in Patriot Incidents'; Wall, 'Dangerous Mix Sparks Scrutiny'; and Michael Smith, 'US 'Clears' Crew Who Shot Down Tornado', the *Daily Telegraph*, 16 July 2003, at <http://www.telegraph.co.uk>.

³¹ Hess, *Ibid.*

³² Author interviews with former government officials in Washington DC in December 2000 and January 2001.

³³ Dennis M. Gormley, 'Counterforce Operations', presentation at Royal United Services Institute for Defence Studies conference on 'Extended Air Defence and the Long-range Missile Threat', London, 17-18 September 1997. For a detailed assessment of the implications of detecting smaller UAV launchers, see Gregory DeSantis and Steven J. McKay, *Unmanned Aerial Vehicles: Technical and Operational Aspects of an Emerging Threat*, PSR Report 2839 (Arlington, VA: Veridian-Pacific-Sierra Research, 2000).

³⁴ As reported by MSNBC, at <http://www.msnbc.com/news/916313.asp?0sl=-21> (accessed 28 May 2003, link now expired). The Kay Report's assessment that only ten HY-2 *Seersuckers* were converted into longer-range land-attack systems suggests that some of the five reported *Seersuckers* fired during the war may have been unmodified anti-ship systems.

³⁵ Tim Butcher, 'Iraq's Missile is a Damp Squib', *Daily Telegraph*, 2 April 2003.

³⁶ For technical details, see Edward Eitzen, 'Chapter 20 — Use of Bio Weapons', in *Medical Aspects of Chemical and Biological Warfare* (Washington, DC: Walter Reed Army Medical Center, 1997), pp. 440-442.

³⁷ The *Seersucker* used to attack the Kuwaiti mall complex appears to have used floating barges nearby the mall to act as contrast targets for its radar guidance system. This appraisal is

based on press reports and the analysis of Dr Gregory DeSantis (telephone interview, 24 September 2003). If they are true, it would appear that this missile was not one of the ten converted land-attack *Seersuckers*, or it may suggest that the Iraqis had failed to master highly accurate navigation over land.

³⁸ For technical details see http://www.brahmos.com/missile_tech.html.

³⁹ For example, although the *Harpoon's* conversion to SLAM permitted the SLAM to be used very accurately over land, the missile has essentially the same 100km-range as the *Harpoon*.

⁴⁰ For more on the use of commercially available navigation, see Gormley, *Dealing with the Threat of Cruise Missiles*, pp. 29–33.

⁴¹ For more on this conversion option, see *ibid.* Converted land-attack *Seersuckers* would be even more difficult to intercept because they would not depend on their active radar, which is susceptible to detection, for terminal guidance.

⁴² The controversy over whether or not the White House exaggerated the threat of Iraqi unmanned drones hinged in part on US Air Intelligence's belief that Iraqi drones had flight management weaknesses, among several others. See David Rogers, 'Air Force Doubts Drone Threat', *Wall Street Journal*, 10 September 2003, at <http://www.lexus-nexus.com>.

⁴³ The author is grateful to Dr Gregory DeSantis for providing survey details on the kit airplane marketplace.

⁴⁴ Richard A. Muller, 'The Cropdusting Terrorist', *Technology Review*, 11 March 2002, at http://www.technologyreview.com/articles/print_version/muller031102.asp.

⁴⁵ Besides the Russian–Indian *Brahmos* cruise missile, Russia has been quietly

marketing shorter-range derivatives of their air-launched AS-15 (Kh-55) and sea-launched 3M-55 cruise missiles. Transfers of critical technologies, such as advanced engines, low-observable, and countermeasure components, could also profoundly affect horizontal proliferation patterns. See Gormley, *Dealing with the Threat of Cruise Missiles*, pp. 81–86 and Douglas Barrie, 'Russian Low-Observable Technology Research Detailed', *Aviation Week & Space Technology*, 11 August 2003, pp. 50–53.

⁴⁶ Cost data on *Patriot* interceptors come from Murray, 'Missile Test'. Of course, the advent of slow-flying UAVs will force American missile defence planners to consider an array of much cheaper ways to defend against such threats. See Gormley, *Dealing with the Threat of Cruise Missiles*, pp. 72–73.

⁴⁷ For the author's own recent treatment, see Dennis M. Gormley, 'UAVs and Cruise Missiles as Possible Terrorist Weapons', in James Clay Moltz, ed., *New Challenges in Missile Proliferation, Missile Defense, and Space Security*, Occasional Paper No. 12 (Monterey, CA: Monterey Institute's Center for Nonproliferation Studies, 2003), pp. 3–9.

⁴⁸ Bradley Graham, 'Cruise Missile Threat Grows, Rumsfeld Says', *Washington Post*, 18 August 2002, p. A1.

⁴⁹ For a discussion of this NIE assessment, see Dennis M. Gormley, 'Enriching Expectations: 11 September's Lessons for Missile Defence', *Survival*, vol. 44, no. 2, Summer 2002, pp. 19–35.

⁵⁰ Daniel Benjamin and Steven Simon, 'The Worse Defense', *New York Times*, 20 February 2003, p. 31.

⁵¹ In theory, the airborne sensor would guide the interceptor during both its

mid-course and terminal phases, or the surface-to-air interceptor could guide itself using its own on-board seeker.

- ⁵² The Defense Advanced Research Projects Agency of the US Department of Defense is pursuing such a cost-reduction effort, primarily focused on cheap missile seekers. See <http://www.darpa.mil/spo/programs/lowcostcruisemissiledefense.htm>.
- ⁵³ For a discussion of some of the challenges of homeland defence against cruise missiles, see Michael Sirak, 'US DOD seeks to bolster cruise missile defences', *Jane's Defence Weekly*, 4 September 2002, p. 3. NORAD has also recently deployed a portable radar enhancement system for spotting low-flying threats, which could prove valuable in protecting a select few high-priority targets. See 'New Air Defense Platform Debuts', *Associated Press*, 21 July 2003.
- ⁵⁴ Sandra I. Erwin, 'Lack of 'Single Integrated Air Picture' Hinders Commanders, Study Says', *National Defense Magazine*, November 2001, at <http://www.nationaldefensemagazine.org/article.cfm?Id=624>.
- ⁵⁵ See, for example, US General Accounting Office, *Combat Identification Systems: Strengthened Management Efforts Needed to Ensure Required Capabilities* (Washington, DC: GAO-01-632, June 2001), at <http://www.defensedaily.com/reports/combatidsystems.pdf>.
- ⁵⁶ In fact, current language is less effective than the original wording of Item 10, which was changed sometime subsequent to 1987 – the regime's inaugural year – in order to remove most case-by-case controls on these technologies. Reverting back to the original 1987 language would actually be better than the current language, but even a more systematic treatment of controls on the means of turning airplanes into UAVs appears worthy of urgent MTCR action. For example, case-by-case controls should apply not only to UAV flight management systems usable in Item 1 systems (missiles capable of delivering 500kg to a range of at least 300km), but Item 19 systems (300km-range missiles independent of payload weight), too. Given that Item 19 systems are ideal means of delivery for biological payloads, UAVs with substantially less than 500kg of payload can produce mass-casualty effects.
- ⁵⁷ Press Release, 'Plenary Meeting of the Missile Technology Control Regime, Warsaw, Poland, 24–27 September 2002', at <http://www.mtcr.info/english/press/warsaw.html>.
- ⁵⁸ 'No-undercut provisions' mean that if one member denies a sale, all must follow. For background details, see Dennis M. Gormley and Richard Speier, 'Controlling Unmanned Air Vehicles: New Challenges', a paper commissioned by the Non-Proliferation Education Center, pp. 13-15, at <http://www.npec-web.org/> and forthcoming in *The Nonproliferation Review*, vol. 10, no. 2, Summer 2003.
- ⁵⁹ For more on missile interceptor transfers, see Amy Svitak and Gopal Ratnam, 'Missile Defense Vs. Non-Proliferation: While House Policy Tests International Limits', *Defense News*, 14 July 2003, p. 1. On the matter of large UAVs, see Gormley and Speier, 'Controlling Unmanned Air Vehicles: New Challenges'.