12. New developments in unmanned air vehicles and land-attack cruise missiles

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I. Introduction

Over 75 000 anti-ship cruise missiles (ASCMs) are deployed by more than 70 countries worldwide. Only about 12 industrialized countries currently produce land attack cruise missiles (LACMs)—most notably exemplified by the US Tomahawk—but this class of cruise missile is expected to proliferate widely by the end of the decade.[1] More widely available is the unmanned air vehicle (UAV).[2] Relegated, until recently, largely to reconnaissance and target-drone roles, the UAV seems likely to become a significantly more prominent means of precise weapon delivery. The Predator reconnaissance UAV has been adapted by the United States to carry two Hellfire missiles and was used in Afghanistan and Yemen to attack al-Qaeda targets. The use of armed Predator UAVs by the USA raises important questions about the kind of expanded roles that UAVs may be adapted to perform in the future and, more immediately, to what extent other countries or terrorist groups might emulate US actions and transform their own unarmed UAVs or piloted light aircraft into unmanned weapon-delivery systems or crude terror weapons. UAV and cruise missile proliferation makes an answer to this question urgent.

This chapter is primarily concerned with UAVs and cruise missiles for land-attack missions. It addresses ASCMs only to evaluate their conversion for land-attack roles. UAVs and cruise missiles represent a generic class of air systems fitted with aerodynamic surfaces that provide lift to keep them airborne during their entire mission. UAVs are reusable systems that are used primarily for reconnaissance purposes. The arming of the predator reconnaissance UAV illustrates the potential for UAVs to become reusable weapon-delivery vehicles. Target drones, employed as air targets for test purposes, are also UAVs that could be converted into weapon-delivery vehicles. In contrast, cruise missiles are always armed and are not reusable. An unmanned combat air vehicle (UCAV) is a new subset of UAV: it is basically a high-performance aircraft autonomously flown by an operator and capable of a variety of lethal and non-lethal missions.

The spread of UAVs and LACMs—even in their crudest versions—poses a host of new risks and challenges. If UAV and LACM proliferation proceeds

[1] Testimony of Central Intelligence Agency Director George J. Tenet before the US Senate Armed Services Committee, 11 Feb. 2003, available at URL <http://www.cia.gov/public_affairs/speeches/dci_speech_02112003.html>.

[2] Also called unmanned aerial vehicles.

unimpeded, it could combine with the further spread of ballistic missiles to give multidimensional offensive forces a distinct advantage over layered defences. This would have negative consequences for homeland defence, regional stability and the spread of potent terrorist capabilities. This reality should energize the search for more effective brakes on the uncontrolled spread of cruise missiles and UAVs.

Given the explosive growth anticipated in UAV systems over the next decade, there will inevitably be increased pressure—led by the USA—to create more flexible, less restrictive, rules governing the export of unarmed UAVs and UCAVs. If adverse international security implications are to be avoided, or at least minimized, effective non-proliferation policy must be elevated to a truly complementary role alongside defence acquisition and security planning. Missile Technology Control Regime (MTCR) participants have now agreed precise ground rules for calculating the range of LACMs. However, other problems remain regarding the transfer of complete LACMs and UAVs and component technologies.[3]

II. The strategic context

The world's UAV inventory is imprecisely documented. According to one recent study at least 40 countries have produced over 600 different types of UAV. Nearly 80 per cent of these have ranges of over 300 km, and many have substantially longer ranges.[4] Moreover, a small fraction of the world's inventory of ASCMs—primarily first-generation models with substantial airframe volumes—could be converted into land-attack missiles with ranges exceeding 300 km. MTCR constraints have major limitations that permit aerospace firms to sell flight management systems specifically designed to turn small manned aircraft (including kit-built ones) into autonomously guided and armed UAVs. If a country, or terrorist group, was motivated to develop a crude cruise missile or UAV, either on its own or with the assistance of a 'rogue state', it could take advantage of the quantum leap, which has occurred in the past 10 years, in the dual-use technologies that comprise the chief components of autonomous air-vehicles. This includes satellite navigation and guidance furnished primarily by the USA's Global Positioning System (GPS), high-resolution satellite imagery from a growing number of commercial vendors and digital mapping technologies for mission planning.[5]

[3] The 33-nation Missile Technology Control Regime governs the transfer of ballistic and cruise missile systems and technology. See chapter 18 in this volume, and the glossary for a list of participants.

[4] DeSantis, G. and McKay, S. J., *Unmanned Aerial Vehicles: Technical and Operational Aspects of an Emerging Threat,* Pacific Sierra Research Report 2839 (Veridian Pacific Sierra Research Corporation: Arlington, Va., 2000).

[5] For details on these and other possible proliferation paths see Gormley, D., *Dealing with the Threat of Cruise Missiles*, Adelphi Paper 339 (Oxford University Press: Oxford, 2001), pp. 17–41; and Pike, J., 'The military uses of outer space', *SIPRI Yearbook 2002: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2002), pp. 613–64.

The impact on US military dominance

If cruise missiles and armed UAVs become a dominant feature of military operations or terrorist activity, the international security consequences will be profound. Ironically, perhaps the most significant repercussions would be felt by the USA—without doubt the most advanced nation when it comes to developing and exploiting LACMs and UAVs for military use. The proliferation of LACMs and UAVs to complement ballistic missiles could conceivably bolster the capacities of states to oppose US-led interventions in strategically important ways. LACMs and UAVs could provide new military leverage, largely because of the capacity of cruise missiles, as a consequence of their aerodynamic stability, to enlarge the effective lethal area of biological attacks by least a factor of 10 over that of ballistic missiles.[6] In addition, LACMs are potentially highly accurate, suggesting that even conventionally armed missiles may be able to inflict significant damage on exposed targets. To envisage such damage, one need only consider the airbases used by US-led coalition forces during Operation Desert Storm, where aircraft were lined up wingtip-to-wingtip and large tent cities were left open and vulnerable to missile attack.

Cruise missile and UAV proliferation is also likely to create unwanted dilemmas for US missile defences. The USA is currently spending huge sums of money to defend against ballistic missile threats.[7] However, to the extent that the USA successfully pursues effective theatre and national missile defences against ballistic missiles, nations and terrorist groups alike will be strongly motivated to acquire LACMs and armed UAVs. The low cost of some cruise missiles and, especially, light aircraft converted into UAVs complicates the cost-per-kill arithmetic of missile defence. For example, each Patriot PAC-3 missile costs $2–5 million, which compares unfavourably with either $200 000 for a LACM or $50 000 for a kit aircraft adapted to become an armed UAV.[8] Because both ballistic and cruise missile defences for theatre campaigns depend largely on the same high-cost, high-performance interceptors, cruise as well as ballistic missile attacks, especially saturation attacks and missiles delivering nuclear, chemical, biological or radiological payloads, will present enormous problems for the defender.

Advanced LACMs that fly low and have low radar visibility will raise the cost of cruise missile defence dramatically.[9] Even seemingly easy-to-detect armed UAVs could challenge advanced air defence radars, including the Airborne Warning and Control System (AWACS) and some ground-based radars. Around 65 per cent of the UAVs deployed today are propelled by reciprocating engines, which means that they fly at speeds of less than 160 km per hour.

[6] Such results are demonstrated in extensive modelling and simulation of biological attacks. McClellan, E., Private communication with the author, 22 Aug. 1997.

[7] See chapter 15 in this volume.

[8] Using entirely off-the-shelf, commercial components, a contractor is developing a prototype ‘affordable’ LACM for the US Navy at a unit cost of less than $40 000. Baard, E., ‘Missiles on a budget: navy meets Home Depot’, *New York Times*, 29 Dec. 2002, p. 4.

[9] For a detailed analysis of cruise missile defence see Gormley (note 5), pp. 59–76.

Expensive air defence radars such as AWACS are designed to screen out slow-flying targets on or near the ground in order to prevent their data processing and display systems from being overtaxed. Although most ground-based air defence radars could probably detect such slow-flying systems, the limited radar horizon of ground-based radars combined with the potentially large number of UAVs involved in an attack means that interceptor batteries could be quickly overwhelmed and their expensive missile inventories rapidly depleted. There are no simple or cheap solutions that readily return the advantage to the defender.

The impact on regional military balances

Existing and future military competitors of the USA will not merely be motivated to acquire long-range missiles to deter or defeat Western-led military interventions. Some states, rogue or not, may be equally or primarily driven to pursue missile acquisition for regional reasons. Thus, regional military balances could also be adversely affected by the spread of LACMs and UAVs. The continuing acquisition by China of M-9 and M-11 ballistic missiles dominates discussion of the China–Taiwan military balance. However, with noticeably less fanfare, both sides have begun to supplement their arsenals with cruise missiles. Closely timed cruise and ballistic missile attacks by China would severely tax the ground-based radars that support the defence of a small number of highly vulnerable Taiwanese airfields.[10]

The unstable balance of forces between India and Pakistan could also be adversely affected by the introduction of cruise missiles and UAVs.[11] In early December 2002, a Pakistani reconnaissance UAV violated Indian airspace near the Kashmiri Line of Control (LOC). It is thought that it was being used to collect battle-damage information.[12] This is one example of a number of similar violations on both sides. The escalation of tension in Kashmir has been mirrored in the broader arms-acquisition domain. Pakistan is seeking to purchase either highly sophisticated Predator UAVs, or perhaps a less controversial system, from the USA to replace its domestically developed, but limited, Vision UAV, in order to improve its monitoring of the LOC.[13]

India is even more active in both its development and its acquisition of cruise missiles and UAVs. Its Lakshya unmanned target drone, thought to be capable of delivering a 450-kg payload over a 600-km range, is reportedly to be exported to an unknown country (probably Israel).[14] Israel, in turn, is supplying India with two Heron long-range reconnaissance UAVs, with more to follow, to support its first major UAV base, located at the southern naval

[10] For a scenario describing how such a plan might plausibly unfold see Gormley, (note 5), pp. 48–50.

[11] Tensions between India and Pakistan are discussed in chapter 5 in this volume.

[12] 'Pak spy plane intrudes into Indian airspace', *Jammu Daily Excelsior* (Internet edn), 8 Dec. 2002, URL <http://www.dailyexelsior.com/web1/02dec08/news.htm>.

[13] Koch, A., 'Pakistan looks to USA to fill UAV gap', *Jane's Defence Weekly*, 2 Oct. 2002, p. 5.

[14] 'India to soon export pilotless target aircraft to "a foreign country"', New Delhi All India Radio, Home News Service, 13 Dec. 2002.

command in Kochi.[15] More controversial, because of its potential impact on the effectiveness of the MTCR, is the co-development by India and Russia of the BrahMos dual-mode (anti-ship and land-attack) supersonic cruise missile, which raises a number of issues regarding the circumvention of arms transfer provisions and the possible range of the missile. Both partners have openly expressed interest in mass export sales of the BrahMos. The most provocative development, however, derives from reports that Russia has agreed to lease India an Akula II nuclear-propelled submarine equipped with 300-km range Club nuclear-capable cruise missiles. Indian military analysts have already begun to characterize India as possessing a 'sea-based nuclear deterrent'.[16]

Cruise missiles are also a factor in tensions in the Middle East. Israel, a major developer of reconnaissance UAVs, has deployed its own Popeye air-launched LACM. It was ballistic missiles that played a central role in the Iraq–Iran 'War of the Cities' in 1980–88. However, while both countries have ongoing ballistic missile development programmes, cruise missiles and UAVs have recently become a part of both nations' arsenal development programmes. Iran has acquired cruise missile technology—probably from China and Russia—for the Nur, its ASCM development programme, which comes in both a ground- and an air-launched version. China has also exported various versions of the Silkworm ASCM to Iran. Older versions, like the HY-2 or HY-4, could be converted into LACMs with ranges of at least 500–700 km.[17] Iraq had a longstanding interest in developing LACMs, including a programme in the 1980s to convert the Italian Mirach 600 UAV into an LACM.[18] More recently, Iraq transformed the Czech L-29 trainer aircraft into unmanned drones, theoretically capable of flying to ranges in excess of 600 km.[19] If Iraq had turned these radio-controlled UAVs into longer-range autonomous systems, this could have had serious consequences if they had been used to deliver biological payloads against regional targets, since an unmanned aircraft's flight stability permits it to effectively release and spray biological agent along a line of contamination.[20] While perhaps only 10 per cent of a liquid anthrax payload might survive the explosive impact of a ballistic missile, nearly the entire capacity of an L-29 spray tank (reportedly 300 litres) would be available for dissemination—a factor of 15 better than ballistic missiles.[21] Iraq's continuing interest in new UAV development was revealed

[15] 'Kochi to become naval center for UAV', *Kottayam Mathrubhumi* (in Malayalam), 19 Dec. 2002.

[16] Nuclear Threat Initiative, 'India: Russia agrees to lease nuclear submarine', Global Security Newswire, 2 Dec. 2002, URL <http://www.nti.org>.

[17] For details on the Nur cruise missile see Middle East News Line, 'Iran claims development of cruise missiles', URL <http://www.menewsline.com/stories/2002/october/10_43_3.html>. For information on converting the Silkworm into a land-attack missile see Gormley (note 5), pp. 30–33.

[18] Carus, W. S., *Cruise Missile Proliferation in the 1990s* (Praeger: Westport, Conn., 1992) pp. 72–73.

[19] Gormley (note 5), pp. 17–18.

[20] Eitzen, E. M., 'The use of biological weapons', eds. D. R. Franz, F. R. Sidell and E. T. Takafuji, *Medical Aspects of Chemical and Biological Warfare* (Borden Institute: Washington, DC, 1997), pp. 440–442.

[21] 'Defending against Iraqi missiles', *IISS Strategic Comments*, vol. 8, no. 8 (Oct. 2002). Effectiveness would depend on variables such as liquid concentration and droplet size or the availability of dry agent and the ability to aerosolize or reaerosolize it. Zanders, J. P., Hart, J. and Kuhlau, F., 'Chemical

by US Secretary of State Colin Powell in his presentation to the UN Security Council on 5 February 2003, when he released classified details of a new Iraqi UAV that had allegedly been tested to a range of 500 km, flying on autopilot, without being refuelled.[22]

The impact on homeland defence requirements

LACMs and UAVs also have strategic implications for homeland defence.[23] In the aftermath of the 11 September 2001 terrorist attacks on the USA, key decision makers started to address these implications.[24] While similar dilemmas are faced by all nations, it is in the USA that the issues are beginning to be addressed seriously.

The fact that a ship-launched LACM fired from just outside territorial waters could strike many of the world's large population centres or industrial areas ought to feature in decisions about protecting domestic populations against missile attack. US National Intelligence Estimates (NIEs) have drawn attention to the possible covert conversion of a commercial container ship into a launching pad for a cruise missile. There are thousands of such vessels in the international fleet. US ports alone handle over 13 million containers annually. Even a large, bulky cruise missile like the Chinese HY-4 Silkworm, equipped with a small internal erector for launching, could easily fit inside a standard 12-metre shipping container. Indeed, the NIEs also argue that, because such an item is less costly, easier to acquire and more reliable than an intercontinental ballistic missile, a cruise missile attack is more likely to occur than a ballistic missile strike.[25]

The offshore option is not the only cruise missile or UAV threat. The absence of more effective controls on fully autonomous flight management systems makes the prospect of the conversion of light aircraft into weapon-carrying UAVs very real. The events of 11 September 2001 provoked a range of reforms to cope with future terrorist use of commercial airliners as weapons. However, these reforms address commercial rather than private aviation. Even though converted light aircraft cannot begin to approximate the effects of an airliner, they can still inflict significant damage on well-chosen civilian targets. Moreover, such means are the most effective method for the delivery of biological agents. Importantly, because such light aircraft could

and biological weapon developments and arms control', *SIPRI Yearbook 2002: World Armaments and Disarmament* (Oxford University Press: Oxford, 2002), pp. 696–703; and Zanders, J. P., *et al*., 'Risk assessment for terrorism with chemical and biological weapons', *SIPRI Yearbook 2000: : World Armaments and Disarmament* (Oxford University Press: Oxford, 2000), pp. 537–59.

22 White House, 'US Secretary of State Colin Powell addresses the UN Security Council', Washington, DC, 5 Feb. 2003, available at URL <http://www.whitehouse.gov/news/releases/2003/02/20030205-1.html>.

23 See section III of chapter 1 in this volume for a discussion of homeland defence.

24 See, e.g., Graham, B., 'Rumsfeld: cruise missile threat rises', *Washington Post*, 18 Oct. 2002, p. A1.

25 For a discussion of NIE assessments and the overall impact on missile defence of the 11 Sep. 2001 attacks see Gormley, D., 'Enriching expectations: 11 September's lessons for missile defence', *Survival*, vol. 44, no. 2 (summer 2002), pp. 19–35.

originate from domestic or domestically based terrorists, they do not necessarily need a hardened strip for take-off—they could therefore be launched from hidden locations, relatively close to their intended targets. Such threats may in part explain why MTCR participants agreed at their 2002 plenary meeting, in Warsaw, Poland, to strengthen efforts to limit the risk of controlled items and their technologies falling into the hands of terrorist groups or individuals.[26]

The challenges and potential costs of defending against both offshore and domestic cruise missile threats are enormous. 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 together with fast-moving interceptors to cope with perceived threats. An architecture of perhaps 100 aerostats at an altitude of 5000 metres could act as a complementary or alternative system of surveillance and fire control for an interceptor fleet. Additional problems remain. A mechanism is required to provide 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. Progress in national cruise missile defence will not be made without corresponding improvements to respective service programmes. However, the latter efforts lack the necessary funding and are hampered by service interoperability, doctrinal and organizational constraints.

The question of affordability looms large. It is safe to assume that even a limited defence against offshore cruise missiles would cost $30–40 billion. This sum is not taken into consideration during current debates about the cost of national ballistic missile defence. Finally, none of these costs or technical challenges pertains to improved defences against domestic 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.[27] In summary, 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.

In the light of the potential impacts that continued cruise missile and UAV proliferation could have on international security, the remainder of this chapter focuses on two additional sets of issues. Section III looks at how countries that have deployed the majority of UAVs and LACMs see them fitting into current and changing military doctrine and national strategy. The USA, in particular,

[26] Missile Technology Control Regime, 'Plenary meeting of the Missile Technology Control Regime, Warsaw, Poland, 24–27 September 2002', Press Release, MTCR/WAR/PL/02/CHAIR/19 Final, available at URL <http://www.mtcr.info/english/press/warsaw.html>. See also chapters 14 and 18 in this volume.

[27] For a discussion of some of the challenges of homeland defence against cruise missiles, see Sirak, M., 'US DOD seeks to bolster cruise missile defences', *Jane's Defence Weekly*, 4 Sep. 2002, p. 3. For a discussion of service programmes and problems see Gormley (note 5), pp. 61–68.

appears to have learned important lessons from the use of UAVs in Operation Enduring Freedom in Afghanistan that may affect future development, procurement and export choices. The USA's new emphasis on 'pre-emption', as incorporated into its national security strategy, may also help define future UAV roles and missions.[28] Section IV addresses non-proliferation policy effectiveness and section V gives the conclusions. All too frequently, defence planners predicate choices on an assumption that non-proliferation will be ineffective. In fact the MTCR, to take one relevant example, has had a decidedly positive effect on controlling the qualitative nature of ballistic missile proliferation.[29] However, the regime has proven less effective at achieving the necessary consensus to deal with the spread of LACMs and UAVs. The close relationship between the latter systems and manned aircraft, as well as the many dual uses of component UAV technologies, make effective controls difficult to fashion. At the 2002 Warsaw MTCR plenary, participants agreed to precise ground rules for calculating the true range of LACMs, a longstanding loophole in the regime's guidelines.[30] Even so, transfers of complete LACMs and critical component technologies need urgent attention.

III. Trends in UAV and LACM developments

Even though ballistic missiles dominated non-proliferation deliberations during the last decade of the 20th century, LACMs—and most prominently the USA's Tomahawk—were used in no fewer than seven military operations. The Tomahawk's most impressive role was reflected in its widespread use against Iraq during Operation Desert Storm when, during the first hours of the air campaign, Tomahawk strikes enhanced the effectiveness of subsequent air attacks by destroying critical Iraqi air-defence and command-and-control targets. Tomahawks also figured in a variety of smaller-scale operations, the most controversial of which were the attacks on the al-Shifa pharmaceutical plant in Khartoum, Sudan and on al-Qaeda camps in Afghanistan, in retaliation for al-Qaeda-sponsored embassy bombings in Africa in August 1998. Although the attack on the al-Shifa pharmaceutical plant received most of the press attention, the ineffectiveness of the LACM attacks on Osama bin Laden's camps in Afghanistan generated military interest in new roles for unarmed, and subsequently armed, UAVs—even before 11 September 2001.

The path to arming the Predator UAV

The Clinton administration considered a variety of military options in response to al-Qaeda's East Africa bombings. Some, especially those involv-

[28] See section II of chapter 1 in this volume for a discussion of the US National Security Strategy.

[29] Speier, R., 'Can the Missile Technology Control Regime be repaired?', ed. J. Cirincione, *Repairing the Regime: Preventing the Spread of Weapons of Mass Destruction* (Routledge: Washington, DC, 2000), p. 206.

[30] Nartker, M., 'International response: MTCR changes address cruise missile proliferation', Nuclear Threat Initiative, Global Security Newswire, 28 Oct. 2002, <http://www.nti.org/d_newswire/issues/newswires/2002_10_28.html>.

ing ground troops, were rejected as too risky. Military strategy focused instead on targeting bin Laden with LACMs stationed on submarines in the Arabian Sea. While such a strategy kept troops out of harm's way, it suffered from enormous operational limitations. The most important was the long delay between acquiring reliable intelligence on bin Laden's precise location and the execution of an actual cruise missile attack. According to White House participants in the planning of such attacks, it normally took about six hours to obtain presidential authority to fire, program the missiles, spin their gyroscopes and get the missiles to the target. Given such a lengthy gap in execution, there was little certainty that the target would still be in place.[31] Frustration led the White House to seek additional military options in the early summer of 2000, one of which included using the Predator UAV to locate bin Laden. Serious organizational rivalries surrounded subsequent moves to ready the Predator for such missions and neither the US Air Force nor the Central Intelligence Agency (CIA) was strongly motivated to move swiftly. Nevertheless, White House pressure led to 12 Predator flights over Afghanistan by October 2000, several of which were thought to have detected bin Laden.

Between taking office in January 2001 and 11 September, the Administration of George W. Bush made no urgent efforts to adapt the Predator to deal with al-Qaeda. It chose instead to focus on a lengthy options appraisal set in the context of an overall review of the terrorist threat. Separately, however, technological momentum led the US Air Force to investigate fitting a missile (the 100-pound, or 45-kg, laser-guided Hellfire-C) to the Predator. The notion of combining real-time eyes, by way of several organic surveillance packages, with a weapon allowing for the virtually instantaneous engagement of 'time-critical targets' was very appealing. Assuming that the authorization to fire could be prearranged, or achieved quickly, such a combined sensor and weapon-carrying UAV would more than compensate for the limitations of using LACMs launched from great distances hours after acquiring targeting intelligence. Even so, organizational and procedural debates, together with the fact that there were too few UAVs to accomplish both reconnaissance missions in Afghanistan and a weapon-testing programme, delayed the arming of the Predator until after the 11 September attacks.[32]

Several procedural, organizational and legal questions dominated consideration of the employment of an armed Predator to target Osama bin Laden. Would the US Air Force or the CIA operate the system? Would permission be needed from the country from which the Predator was operated? Who, ultimately, would authorize the decision to fire? Could a prearranged list of approved targets provide sufficient authorization? While these questions were being debated in the White House, National Security Council officials put pressure on the US Air Force to reduce the Predator's test programme from three years to three months. Organizational rivalries surrounding control and decision-making authority evaporated in the aftermath of the 11 September

[31] Benjamin, D. and Simon, S., *The Age of Sacred Terror* (Random House: New York, 2002), p. 294.
[32] Benjamin and Simon (note 31), pp. 336–38.

attacks. Within two weeks the armed Predator was flying over Afghanistan searching for al-Qaeda target opportunities and on 15 November 2001, two Hellfire missiles launched from a Predator killed Muhammad Atef, al-Qaeda's chief of military operations.[33]

The events of 11 September 2001 opened up a debate on a new role for the armed UAV. On 3 November 2002, a CIA-operated armed UAV flying over Yemen, with Yemen's approval, killed a top al-Qaeda operative and five companions travelling in the same car. The event raised a number of questions regarding motivation and legality. However, speculation mounted that the USA was examining the feasibility of further uses of this method, including the killing of Hezbollah leaders linked to the deaths of US soldiers and civilians in the 1980s.[34] Indeed, such a proposal was publicly raised during a Senate Judiciary Committee hearing in late November 2002, and supported by the Committee's chairman, Senator Arlen Specter.[35]

Lessons from Afghanistan and the Bush doctrine of pre-emption

UAVs will figure prominently in military planning associated with the USA's new emphasis on pre-emption, which essentially reserves the right for the USA to attack potential enemies before they strike first.[36] The option of pre-emptive action broadly fits into US Secretary of Defense Donald Rumsfeld's view of a transformed US military. Upset about the length of time it has taken to build up responses to military crises, Rumsfeld foresees a US military that can conduct decisive operations with rapidly deployable, agile, stealthy forces able to respond to contingencies, both large and small, with a minimum of logistical support. In such scenarios, the quality of networking between sensors and weapon-delivery systems would be more important than the number of weapons platforms. The ubiquitous employment of microprocessors throughout military systems; remote sensing technologies, as employed on UAVs; advanced data-fusion software; interlinked but physically disparate databases; and high-speed, high-capacity communications networks would facilitate the precise delivery of force against the most important time-sensitive enemy targets. While sequential attacks against these targets would allow the enemy time to recover or hide, networked sensors and weapon-delivery systems would produce simultaneous fire, improving effectiveness by an order of magnitude.

Arming the Predator UAV exemplifies this transformation in targeting. A decade earlier, in Operation Desert Storm, US forces received relatively poor support from overhead reconnaissance and surveillance systems, at the time

[33] Benjamin and Simon (note 31), pp. 346–49.

[34] 'US weighs assassination options after Predator success', World Tribune.com, 29 Nov. 2002.

[35] World Tribune.com (note 34).

[36] Frankel, G., 'New US doctrine worries Europeans', *Washington Post*, 30 Sep. 2002, p. A1, gives an account and European reaction. Allen, M. and Gellman, B., 'Preemptive strikes part of strategy, officials say', *Washington Post*, 11 Dec. 2002, p. A1, gives an account of the doctrine's further application to dealing with weapons of mass destruction.

the exclusive domain of the national intelligence community. Space-based communications support also produced inadequate results, and such support was critically unavailable to military forces in Somalia in 1993. Circumstances in Afghanistan proved radically different. Operation Enduring Freedom demonstrated the capacity of geographically dispersed forces to observe substantially the same battlefields simultaneously. This broadly based battlefield awareness allowed mass effects—that is, widely distributed precision attacks that occur simultaneously—to be achieved without the necessity of massing forces, thereby reducing vulnerability. Near-real-time video images from Predator and Global Hawk UAVs—under the control of military commanders rather than the intelligence community—were relayed via communications satellites to command centres and individual air-controllers on the ground. These air-controllers could point their laser binoculars at targets and instantly pass precision bearing and range information (translated into latitude and longitude by a GPS receiver) to command centres and aircraft circling nearby. Combat aircraft armed with Joint Direct Attack Munitions (JDAMs), relatively cheap modifications to existing unguided bombs enabling them to be guided precisely by GPS signals to their targets, could then 're-program' their bombs to deliver them with remarkable accuracy. This capacity to broaden battlefield awareness through UAVs and space-based communications enabled the USA's regional commander to direct battle operations from his headquarters in Tampa, Florida, while being instantaneously connected to his forward headquarters in Kuwait and a subordinate headquarters in Uzbekistan.

The increasing role of UAVs imposes additional burdens on military space assets. A growing indication of their importance is the huge increase in bandwidth requirements over the past decade. The provision of near-real-time video from Predator UAVs to AC-130 gunships, for example, allows gunship crews to be briefed with live imagery well before they reach their targets. However, a significant amount of bandwidth is required to accomplish such applications. The Pentagon leased 800 megabits per second (Mbps) of commercial satellite support for Operation Enduring Freedom compared with 100 Mbps during Operation Desert Storm—a seven-fold increase to support one-tenth the number of forces. The Predator's role has expanded beyond simply furnishing high-resolution real-time video to include radar, infrared and colour video that permits the system to track vehicles at night and through cloud. Global Hawk flies at over three times the altitude of the Predator and thus provides a broad area tracking and mapping capability through the use of high-resolution synthetic aperture and moving target indicator radar systems. As these systems become increasingly useful, bandwidth requirements and the dependence on space to prosecute the new style of warfare will also increase.

The arming of the Predator provides a new instrument for US military doctrine. In Afghanistan, the US military demonstrated how airpower can be employed in near-simultaneous, rather than sequential, waves through the rapid integration of sensor data into the allocation of aircraft, manned or unmanned. Ground combat air-controllers during Operation Enduring Freedom called in fighter aircraft, heavy bombers and even armed Predators from just outside the target area to hit targets, including fleeting ones, identified and subsequently approved for targeting within minutes of their disclosure.

Overall, however, the US military is a long way from realizing the profound transformation that Rumsfeld contemplates. While the build-up of military forces arrayed against Iraq occurred more rapidly than it did in 1990–91, the military remained caught between its traditional dependence on heavy platforms and Rumsfeld's inclination to implement a lightweight force structure. Even so, preliminary lessons drawn from the war in Afghanistan support the emerging notion of network-centric warfare, particularly insofar as it reduces the time between target detection and attack. Armed UAVs, cruise missiles, and eventually UCAVs will accelerate the implementation of Rumsfeld's vision.

Prospects for unmanned vehicles in military applications

What distinguishes armed UAVs from manned aircraft in such roles is their capacity to remain on standby, in the air, for periods of 24 hours or more without exposing a piloted and expensive aircraft to enemy fire. US military planners foresaw a role for armed and unarmed Predators in Iraq, particularly against critically important fleeting targets in and around Baghdad that were too risky for manned aircraft to pursue. However, by November 2002, the US Air Force possessed only about 50 Predators and only a small number were equipped to fire Hellfire missiles.[37] The CIA also has a small number of armed Predators and new versions are being produced at the rate of about two per month. These drones have several operational weaknesses, including problems with flying in bad and icy weather and vulnerability to anti-aircraft fire. At least 10 Predators crashed during missions over Afghanistan or Iraq between October 2001 and November 2002.

Plans are afoot, however, to develop and produce improved versions of the Predator. The model currently in operation, the MQ-1B, is powered by a simple reciprocating engine, which gives it a speed of 80 knots. A much faster (about 260 knots airspeed) and higher-flying version with a turboprop engine—the MQ-9B, or Predator B—has already been built. Three or four more will follow in 2003, and production will increase to nine and then to 15 annually thereafter. Another version of the Predator B, with a 6-metre wing extension, will be able to stay in the air for 42-hour missions carrying two external drop tanks and 1000 pounds (*c.* 450 kg) of weapons. While current Predators are restricted to carrying Hellfire missiles, future versions will carry a variety of more potent weapons, including 250- and 500-pound (113- and 225-kg) JDAMs and two different air-to-air missiles. Newer versions of the Predator are expected to cost about $4 million, roughly double the cost of the current model.[38] In view of the Predator B's capacity to remain on station for

[37] Schmitt, E., 'US would use drones to attack Iraqi targets', *New York Times*, 6 Nov. 2002, p. A1.

[38] Fulghum, D., 'Predator B to increase lethality of UAV fleet', *Aviation Week & Space Technology*, 11 Nov. 2002, p. 34.

nearly two days without pilot fatigue, refuelling, or wear-and-tear on limited inventories of advanced high-performance F-15s or F-16s, such armed UAVs are considered excellent value, at least for specialized missions requiring long standby periods in the air and operating in air-defence environments where manned aircraft would be unduly taxed or vulnerable.

Current LACMs in the US arsenal cannot be directed remotely after launch to attack fleeting targets. However, in early November 2002, the US Navy completed the demonstration test flight phase of a programme aimed at the remote redirection of LACMs after launch. Called the Tactical Tomahawk, this eventual replacement for the current US Navy Tomahawk will be capable not only of striking one of 15 pre-programmed targets, but also of receiving a last-minute change to an entirely new target. Thus, future LACMs will be able to remain over the battlefield like today's armed Predator drones (albeit for hours rather than days) and adapt much more effectively to fleeting targets. Moreover, the tactical Tomahawk will also be equipped with a video camera to give ground commanders additional battlefield awareness. The US Navy plans to begin deploying the Tactical Tomahawk aboard its submarines and ships in 2004. Over 1300 are currently being procured at a unit price of roughly $575 000, or about half the cost of the current Tomahawk LACM.[39]

UCAVs, unmanned high-performance aircraft that many analysts believe represent a profound change in the US style of warfare, constitute a potentially more valuable but less certain complement to the US military transformation than armed UAVs or more flexibly targeted LACMs. The Pentagon's Defense Advanced Research Projects Agency (DARPA) is currently co-sponsoring, with the US Air Force, a Boeing UCAV prototype, the X-45A, that had conducted five test flights by the end of 2002. Although officially, the primary mission of the UCAV prototype is air defence suppression, others have been mentioned, including delivery of directed-energy (high-powered microwave, HPM) weapons and even conventional weapons such as JDAMs. At such an early stage, it should come as no surprise that there is a degree of uncertainty about UCAV development. Some, including James Roche, the Secretary of the US Air Force, are concerned that a highly dynamic mission such as air defence suppression requires a pilot and that less active missions such as strategic bombing may be more suitable for future UCAVs. Also muddying the waters are discussions within the Pentagon about incorporating US Navy requirements into the X-45A to achieve a multi-service UCAV programme along the lines of the Joint Strike Fighter project.[40] Close allies of the USA, in particular the UK, have begun to see a more prominent role for both UCAVs and UAVs. The UK is exploring opportunities to become involved in UCAV development with the USA. It has begun a UAV programme of its own, called Watchkeeper, which has many of the features of the Predator. One of several motivating factors for the UK is keeping pace with the USA's emerging doc-

[39] Anderson, H., 'New cruise missile passes test flight', United Press International News Service, 12 Nov. 2002.

[40] Wall, R., 'Uncertainty engulfs Pentagon's unmanned aircraft plans', *Aviation Week & Space Technology*, 16 Sep. 2002, pp. 27–28.

trine of network-centric warfare.[41] Nevertheless UCAVs, as distinct from UAVs and LACMs, are likely to remain a future requirement rather than a practical reality until numerous bureaucratic, doctrinal and industrial challenges have been overcome.

A combination of technological and policy factors will continue to shape the pace and scope of future UAV prospects. Without doubt, enormous advances in computer processing power, sensor technology, communications, and imagery processing and exploitation have greatly advanced UAV performance. However, technological advances are constrained as well as driven by policy considerations. LACMs like the Tomahawk languished for nearly two decades before they came to prominence during Operation Desert Storm. Although Firebee reconnaissance drones flew thousands of sorties during the Viet Nam War, there was a significant delay before the technological leap to the Predator was made. Service resistance, determined in part by a continued preference for manned aircraft, will remain an important constraining factor. Nevertheless, new requirements for so-called battlefield awareness, increased pressure by the public and political leaders alike to avoid casualties, and technological momentum have converged to accelerate UAV applications.

In any event, UAVs will not proliferate widely until there is a corresponding development of operational concepts and doctrines for their use in combat. The US Air Force's UAV Battlelab is currently struggling with such operational concepts built around the notion of network-centric warfare. Armed and reconnaissance UAVs, together with more flexibly targeted LACMs, such as the Tactical Tomahawk, would be launched into the so-called Global Information Grid—or a theatre of operations characterized by ubiquitous sensor systems and highly integrated command and control systems. By the next decade, UCAVs and large numbers of micro-UAVs (less than 30 cm long and capable of both weapon delivery and reconnaissance missions) would become part of the concept. The Grid would provide joint forces operating within its physical space with a single, secure, end-to-end information system allowing those with access to share data and applications.[42] Autonomous attack systems, deployed within the Grid, would await targeting instructions from local command authorities. There were early signs of such an operational concept in Operation Enduring Freedom. However, the critical challenge will be to tighten the decision-making process to reduce the cycle from detection to strike to less than five minutes, which the US Air Force considers to be the ultimate objective. Part of that challenge is technical—automated filtering of false targets from real ones remains difficult because target recognition technology has not kept pace with adversary deception techniques. There is still a risk that a school bus might be mistaken for a mobile missile launcher. There is also the human dimension. During Operation Enduring Freedom, an armed Predator detected a Taliban leader entering a building, but central command

[41] Barrie, D., 'Britain determines military net value', *Aviation Week & Space Technology*, 23 Dec. 2002, pp. 53–55.

[42] Morris, J., 'Air Force developing new CONOPS for loitering lethal UAVs', *Aerospace Daily*, 17 Dec. 2002, p.1.

authorities in Tampa, Florida, were uncertain of how they should handle the situation, from a legal rather than technical perspective, and the opportunity to strike was missed.[43]

Even if developments in shared battlefield awareness and precision targeting were to revolutionize the way airpower is delivered, the notion that definite and rapid military success regardless of operational circumstances would be assured seems dubious. Several important caveats must be kept in mind. While Operation Enduring Freedom demonstrated that modern airpower has made the transition from targeting large numbers of fixed targets to handling fleeting ones as well, it is possible to imagine far more unforgiving terrain than Afghanistan and Iraq. Finding and swiftly targeting small bands of terrorists or their supporters is difficult enough in Afghanistan, but vastly more difficult in other natural topographies or urban settings. Prosecuting fleeting targets in more complex operating environments will require more than improvements in UAV orders. It will call for breakthroughs in other technological areas such as foliage penetration radar, micro-UAVs, variable-effect munitions and robotics, to name just a few. Indeed, technological advances may turn out to be a necessary but not a sufficient tool to deal with operational challenges. US military forces in Afghanistan reportedly failed to capitalize on a number of opportunities to kill or capture key al-Qaeda and Taliban forces in the battle of Tora Bora and during Operation Anaconda.[44] Risk aversion appears to have led to an initial decision to depend more on lightly armed UAVs, high-altitude airpower and local forces rather than commit large numbers of US troops.[45]

Other applications for unmanned vehicles

Military missions in overseas settings are not the only possible application for UAVs. Homeland security applications abound. The US Coast Guard plans to acquire 76 UAVs capable of being launched from ships or land. These would be used to monitor coastlines for security threats and illegal drug traffic, for fisheries enforcement and possibly in support of search-and-rescue operations. Countless other civil and commercial applications are conceivable—from monitoring traffic flows, protecting critical infrastructure facilities and searching for fugitives, to a host of agricultural jobs—but an unfavourable regulatory environment in the USA inhibits virtually all of these applications.

The FAA has yet to authorize the regulated use of UAVs over domestic airspace, except for a handful of exceptions requiring specific certification and a trailing piloted aircraft to ensure that the UAV does not enter restricted airspace.[46] The chief regulatory concern is collision avoidance. Some industry groups are therefore backing a proposal to fly UAVs above 12 000 metres—higher than domestic commercial air traffic. However, the problem is more

[43] Kaufman, G., 'New eyes, new rules: US need for better ISR drives doctrine, acquisition, organization', *Defense News*, 2 Dec. 2002, p. 1.

[44] See chapter 4 in this volume for a discussion of events in Afghanistan, including the attack in Dec. 2001 on the redoubt at Tora Bora and Operation Anaconda, launched in Mar. 2002.

[45] For one such account see Lemann, N., 'The war on what?', *New Yorker*, 16 Sep. 2002, pp. 36–44.

[46] Merle, R., 'Drones at home: big market, big concerns', *Washington Post*, 1 Jan. 2003, p. E1.

complex, not least because the current generation of UAVs, including military ones, has not undergone the kind of rigorous aerospace quality manufacturing procedures typical of manned aircraft. (This may also explain why the US Air Force has suffered crashes with three of its six Global Hawk UAVs and about half of its 50 Predators).

In short, while UAV use in Afghanistan may have prompted hopes of a change in the attitude of regulators, significant obstacles stand in the way of major growth for civil and commercial purposes. Oddly, the FAA seems not to have focused on the potential terrorist use of UAVs. The agency has been most concerned about collision avoidance between 3000 metres and 12 000 metres. Terrorist applications are most likely to occur below 3000 metres, closer to a wider range of targets and where detection by either NORAD or FAA radars becomes problematic.[47] In at least one case— admittedly, one that occurred prior to 11 September 2001—the FAA approved the use of a UAV for agricultural applications on the curious conditions that the vehicle's wingspan not exceed 114 inches (290 cm), that it be flown below 3000 metres and that it be called a 'model airplane' rather than a UAV. Ironically, it is a model aircraft's very small size that allows it to fit into the largest Federal Express package for shipment around the globe. Such restrictions may be convenient from an air safety standpoint. However, such 'model airplanes', however limited their payload capacity (probably 15–30 kg), can still be equipped to deliver enough biological agent to produce potentially devastating effects.

What future for pre-emption?

If the doctrine of pre-emption has limited application in the fight against terrorism, it has comparable limits vis-à-vis states armed with nuclear, biological or chemical weapons and the missiles to deliver them. Any strategy organized around the notion of pre-empting such threats critically depends on achieving near-perfect results in three chronically difficult areas.[48] The first is finding, identifying and destroying deeply buried facilities where weapons of mass destruction (WMD) are increasingly located. Commercially available boring equipment enables states such as the Democratic People's Republic of Korea (North Korea), Iran and Iraq to excavate deep tunnels and create large underground facilities that may be susceptible to detection but impossible to recognize with any precision and equally impossible to destroy with existing conventional weapons.

The second area is that of finding and attacking elusive targets, most importantly WMD-armed ballistic or cruise missiles. As noted above, some improvement has occurred in reducing the time between detection of fleeting

[47] Interview by the author with an industry official, 14 Apr. 2001.

[48] Requirements for countering WMD threats were first articulated by Secretary of Defense Les Aspin. Aspin, L., 'The Defense Department's new nuclear counterproliferation initiative', Address to the National Academy of Sciences, Committee on International Security and Arms Control, Washington, DC, 7 Dec. 1993.

targets and execution of attack plans, but such progress against elusive terrorist targets in the midst of a campaign dominated by US airpower does not begin to approximate the challenge of pre-emptively finding and attacking hidden mobile missile units before they can launch their WMD-armed missiles. UAVs, particularly ones such as the high-flying Global Hawk, can certainly help with the critical surveillance mission, but most analysts foresee little progress in achieving breakthroughs until truly wide-area surveillance systems are available. This would entail the deployment of a large constellation of space-based radar satellites, in either low- or mid-earth orbits, focused on monitoring missile facilities and deployment activities around the clock—not unlike anti-submarine warfare operations during the cold war. The Bush Administration has resurrected the Discoverer II space-based radar system—previously terminated by Congress—but, even with accelerated spending, any meaningful space-based radar constellation would probably not become operational until 2010.[49] Furthermore, the production of automated target recognition software needed to distinguish real from false targets may not keep pace with the evolving nature of threats. Today's Scud ballistic missile launchers are relatively easy to distinguish from smaller military and civilian vehicles. However, as ground-launched cruise missiles become a more prominent threat, targeting difficulties will be compounded—the percentage of civilian and military 'look-alike' vehicles will more than double as smaller cruise (and even ballistic) missile launchers proliferate.[50]

The third, and no less daunting, area required for successful pre-emption is to shoot down enemy missiles that survive the counterforce campaign, or are launched before counterforce strikes are undertaken. US ballistic missile defence (BMD) programmes have experienced staggering delays, technical problems and conflicting political objectives, while inadequate funding and military service reluctance to implement truly joint solutions currently undermine cruise missile defence (CMD) programmes. Critics of the USA's BMD efforts argue that the 'hit-to-kill' technology, on which almost the entire programme is predicated, is fundamentally flawed because of its susceptibility to simple countermeasures. Implementing CMD programmes, whether for theatre or homeland defence, is in its infancy and is similarly susceptible to saturation attacks—particularly in the event that cheap cruise missiles proliferate widely. Whether or not simple countermeasures represent the Achilles heel of missile defence, multi-layered missile defence programmes for either overseas or homeland defence will not begin to be deployed until late in this decade.

These issues have implications far wider than UAVs, but illustrate another area where developments in UAV technology are double-edged. On the one hand, such systems are at the heart of efforts by the USA to develop the capa-

[49] Morris, J., 'Northrop Grumman pushing to accelerate space-based radar to achieve IOC by 2010', *Aerospace Daily*, 17 July 2002, p. 1.

[50] For the results of 1 government-sponsored study of this problem see Gormley, D., 'Counterforce options', Presentation made at the Royal United Services Institute for Defence Studies, Conference on Extended Air Defense and the Long-Range Missile Threat, London, 17–18 Sep. 1997.

city to execute a pre-emptively oriented military strategy. On the other, these very systems—and even much cruder versions—in the hands of adversaries of the USA could present overwhelming hurdles to the implementation of such a strategy. Thus, if UAV and LACM proliferation proceeds unimpeded, it could combine with the further spread of ballistic missiles to give multidimensional offensive forces a distinct advantage over layered defences, with unstable consequences not just for the USA but also for regional stability and the spread of potent terrorist capabilities.[51]

IV. Implications for non-proliferation policies

Calls to transform the MTCR from a voluntary supplier's regime into a universal, legally binding treaty are as old as the regime itself.[52] Through its various disarmament mechanisms, the UN has consistently expressed the need for a universally accepted norm governing the development, testing, production, acquisition, transfer, deployment and use of missiles. UN efforts to facilitate such norm creation have achieved little of substance. For example, the report of a UN panel of governmental experts (with participants from 23 countries) on 'missiles in all aspects' failed to agree on a single recommendation for a course of action, or even a joint understanding about the nature of the problem.[53] A more substantive manifestation is represented by international efforts, largely by MTCR participants, to develop an International Code of Conduct Against Ballistic Missile Proliferation.[54] However useful international norms (not legally binding in the case of the code) might be, it is virtually impossible to conceive of a formal, legally binding treaty regime that could adequately address the problem of missile proliferation. This caveat applies with particular force to cruise missiles and UAVs, the very features of which (small size, modularity, conversion potential, multiple uses, etc.) render them difficult to manage under the MTCR. Negotiating such a treaty, let alone verifying it, would be a profoundly daunting endeavour, and one that would surely take years and inevitably sap efforts to improve the effectiveness of the MTCR.

Not surprisingly, many advocates of missile defences view missile non-proliferation—principally in the guise of the MTCR—as an abject failure.[55] However, the regime's performance could more accurately be characterized as somewhere between partially flawed and helpfully effective. Its imperfections aside, the MTCR—the only extant multilateral arrangement covering the

[51] For 1 such argument about the advantages of offence over defence see Vickers, M. G., *Warfare in 2020: A Primer* (Center for Strategic and Budgetary Assessments: Washington, DC, 1996), p. 5.

[52] For an overview and analysis see Gormley (note 5), pp. 90–91.

[53] United Nations, Report of the Secretary-General: the issue of missiles in all its aspects, UN document A/57/229, 23 July 2002; and Smith, M., 'Stuck on the launch pad? The ballistic missile code of conduct opens for business', *Disarmament Diplomacy,* no. 68, Dec. 2002–Jan. 2003.

[54] Gormley, D., 'A ballistic missile code of conduct: just how valuable?', IISS Strategic Pointers, 21 Feb. 2002, URL <http://www.iiss.org/pub/sp/sp02002.asp>. See also appendices 18A and 18B in this volume.

[55] See, e.g., Tanks, D., *Assessing the Cruise Missile Puzzle: How Great a Defense Challenge?* (Institute for Foreign Policy Analysis: Washington, DC, 2000).

transfer of missiles (ballistic and UAVs), related equipment, material and technology relevant to WMD delivery—has achieved notable success in controlling the spread of ballistic missiles. The regime's substantial accomplishment in denying the export of dual-use components, technologies and production capabilities relevant to ballistic missiles has gone largely unnoticed. In the late 1980s, the MTCR succeeded in pressuring Argentina to dismantle its Condor ballistic missile programme. As a consequence of the MTCR, the spread of ballistic missiles to date is largely limited to 50-year-old Scud technology, a derivative itself of the World War II German V-2 programme. This achievement makes missile defences more practical, as they can exploit many of the weaknesses of this level of rudimentary missile technology.[56]

Sadly, however, the MTCR's provisions are substantially more effective in controlling ballistic missiles than cruise missiles and UAVs. Several reasons explain this discrepancy. For one, there is a reasonably solid consensus among MTCR participants in favour of restricting ballistic missiles, while the same is not true for cruise missiles and particularly, UAVs. Second, because the MTCR exempts manned aircraft and related technologies from any controls, states and terrorist groups can exploit these technologies over time to develop cruise missiles and UAVs. Finally, the provisions of the MTCR's equipment and technology annex, because they apply to cruise missiles and UAVs, have not kept pace with the extraordinarily rapid expansion in commercially available technology facilitated by a globalized economy. Moreover, new and old types of unmanned systems currently subject to MTCR controls—UCAVs and Lighter-Than-Air (LTA) systems, respectively—raise important questions about the nature of their treatment as 'cruise missiles or UAVs'.

An emerging consensus?

Because LACMs and UAVs have not yet proliferated widely, it is vitally important to address these weaknesses promptly. In the USA, there are signs that these MTCR shortcomings are beginning to command the attention they deserve. A panel of the US Senate Committee on Governmental Affairs held three hearings between February and June 2002 to address the threat of cruise missiles and UAVs, export-control effectiveness, and the quality of cruise missile and UAV intelligence assessments.[57] In late 2002, the Committee on

[56] See Gormley (note 5), pp. 77–78.

[57] Ruppe, D., 'US response I: shore up multilateral regimes, experts testify', Nuclear Threat Initiative, Global Security Newswire, 14 Feb. 2002, URL <http://www.nti.org/d_newswire/issues/2002/2/14/2s.html>; Siegle, G., 'Threat assessment I: cruise missiles getting attention, CIA official says', Nuclear Threat Initiative, Global Security Newswire, 12 Mar. 2002, available at URL <http://www.nti.org/d_newswire/issues/2002/3/12/9s.html>; US Senate, Committee on Governmental Affairs, International Security, Proliferation, and Federal Services Subcommittee, Hearing on CIA National Intelligence Estimate of Foreign Missile Development and the Ballistic Missile Threat through 2015, 11 Feb. 2002, URL <http://www.senate.gov/~gov_affairs/031102witness.htm>; Hearing on Multilateral Non-proliferation Regimes, Weapons of Mass Destruction Technologies, and the War on Terrorism, 12 Feb. 2002, URL <http://www.senate.gov/~gov_affairs/021202witness.htm>; and Hearing on Cruise Missile and UAV Threats to the United States, 11 June 2002, URL <http://www.senate.gov/~gov_affairs/061102witness.htm>.

Government Reform of the House of Representatives asked the General Accounting Office (GAO) to undertake an extensive review of cruise missile and UAV proliferation, with particular attention to the effectiveness of existing non-proliferation policies.[58]

Delineating precisely which cruise missile and UAV-related technologies to restrict proved more difficult than composing a list of ballistic missile technologies. Consensus had previously developed around a 'strong presumption to deny' the export of certain complete cruise-missile systems and technologies—so-called Category I items. However, putting the Category I proscription into practice has proved more daunting and potentially more disruptive than originally anticipated. Most notably, France and the United Kingdom, co-producers of the Black Shaheen LACM, a derivative of the French Apache and British Storm Shadow, decided in 1997 to sell the missile to the United Arab Emirates. The governments of France and the UK approved the sale in spite of the fact that the Black Shaheen—along with the Apache and Storm Shadow—was capable of carrying a 500-kg payload to a range exceeding 300 km. Although MTCR participants may, on rare occasions, make an exception to the 'strong presumption to deny' such exports, the Black Shaheen deal raised the spectre of other MTCR participants, most notably Russia and China, taking advantage of the confusion over how to determine the true range of cruise missiles and UAVs to provide a rationale for their own Category I sales. What was clearly missing was a consensus on determining UAV range.

Determining the true range of ballistic missiles involves a relatively straightforward calculation of the missile's maximum range trajectory from its point of launch to its target. Defining a cruise missile's range involves a greater number of variables. Such systems can be launched not only from the ground but also from airborne platforms. States and cruise missile manufacturers frequently quote a missile's range on the basis of a low flight profile, which is useful in avoiding detection. However, cruise missiles need not fly their entire distance using such low flight profiles. They can be launched at or reach a range-maximizing altitude and then drop to a terrain-hugging profile when they become more susceptible to detection. Such a range-maximizing profile can extend a cruise missile's range by a factor of three over a low flight profile. At the Berlin technical experts meeting in July 2000, discussions began in earnest on ways of reducing ambiguities over range and payload, leading to the September 2002 announcement at the Warsaw plenary that revised definitions of range and payload had been approved for immediate implementation.[59] By adopting the same range-maximizing principle that applies to determining the true range of ballistic missiles, MTCR participants demonstrated their intention to treat cruise missiles and UAVs with the degree of scrutiny traditionally reserved for ballistic missiles.

In spite of the emerging consensus on the need for more effective cruise missile controls within the MTCR, the behaviour of certain states regarding

[58] Interview by the author with GAO staff, 16 Dec. 2002.

[59] Nartker (note 30).

exports of LACM/UAV systems and technology components remains a serious proliferation concern. Many states regard the MTCR as a restrictive arrangement that does not represent their interests adequately. Primarily driven by strong financial incentives, Russian cruise missile entities have furnished China with critical support for its emerging LACM programmes.[60] As mentioned above, Russia's co-development with India of the BrahMos cruise missile raises important questions about Moscow's adherence to the MTCR's technology transfer guidelines. India is not, and is unlikely to become, a participant and the Indian Government is interested in developing the Middle East market for potential cruise missile and UAV sales.[61] China's idiosyncratic adherence to the MTCR's norms suggests that LACM transfers will not receive the same scrutiny that other participants provide. In 1994, China agreed not to export ground-to-ground missiles, meeting the original 1987 range and payload parameters of the regime. This excluded air-to-ground cruise missiles. In late August 2002, however, China issued an extensive control list of missile items, specifically including cruise missiles and UAVs. In effect, this device conflated Category I and Category II items into Category II, omitting the MTCR's strong presumption of denial for Category I items and subjecting them purely to case-by-case licence reviews. Moreover, the new control list does not cover missiles with a range of 300 km or more, independent of payload weight. Participants in the MTCR added such a provision in 1993 (Category II, Item 19) out of concern that biological and chemical payloads did not require a 500-kg payload to produce mass-destruction effects. Chinese intentions regarding LACM and UAV transfers will therefore remain problematic until China is willing to become a full participant in the regime.

Coping with enduring and new challenges

The MTCR does not cover exports of civilian or military manned aircraft. As important, the regime intentionally exempts critical Category II sub-systems as long as they are intended for manned-aircraft programmes. This means that states can employ circuitous paths to acquire the necessary component technologies for LACMs and UAVs. The structures, propulsion systems, autopilots and navigation systems used in manned aircraft are essentially interchangeable with those of cruise missiles and UAVs.[62] Cruise missile development could be conducted under the auspices of an apparently legitimate manned aircraft programme. Indeed, as Iraq demonstrated by converting the Czech L-29 trainer aircraft and the Soviet MiG-21 fighter into unmanned sys-

[60] For more on Chinese LACM programmes see Lennox, D., 'China's new cruise missile programme "racing ahead"', *Jane's Defence Weekly*, 12 Jan. 2000, p. 12; and Stokes, M. A., *China's Strategic Modernization: Implications for the United States* (Strategic Studies Institute, US Army War College: Carlisle, Pa., Sep. 1999), pp. 79–86.

[61] Raguvanshi, V., 'India targets Middle Eastern market', *Defense News*, 19 Mar. 2001, p. 1.

[62] Nearly a decade ago, the sale of turbofan engines to China by AlliedSignal illustrated the tension between industrial sales and proliferation concerns. McMahon, K. S. and Gormley, D. M., *Controlling the Spread of Land-Attack Cruise Missiles* (American Institute for Strategic Cooperation: Marina del Rey, Calif., 1995), p. 25.

tems, states need not start from scratch to develop cruise missiles for land attack missions. Nevertheless, it is important to bear in mind that if states of concern somehow manage to exploit these exemptions on manned aircraft components, or convert ageing aircraft into unmanned systems, they are still forced, in the first case, to pursue much longer development paths to acquire, in both cases, fairly primitive and vulnerable first-generation cruise missiles. This reality underscores the importance of building a solid and enduring consensus within the MTCR for tightening controls restricting the proliferation of advanced LACMs and UAVs and a handful of related component technologies. MTCR participants' decisive tightening of cruise missile range and payload definitions at the Warsaw plenary meeting may signal an increased willingness to address several new non-proliferation challenges central to controlling the spread of advanced systems. On the other hand, the technical and political difficulties should not be underestimated.

In any event, MTCR interest in limiting the risks that controlled items might fall into the hands of terrorist groups and individuals ought to impel participants to investigate how better to control flight-management systems that would rapidly transform innocent light aircraft into terrorist weapons. Nothing can be done about the ease of acquiring cheap kit-built aircraft—by one estimate about 100 000 copies of over 400 different systems are readily available for purchase from manufacturers worldwide.[63] The same holds true for more expensive but even more widely available private aircraft.[64] The hardest part of transforming a kit or small private aircraft into a weapon-carrying autonomous attack system is developing and integrating a fully autonomous flight-management system into the aircraft. States are capable of such transformations, but it is doubtful that a terrorist group could develop and integrate autonomous flight controls into such aircraft without help. Such help may be available, however. A handful of small aerospace companies in the USA now offer fully autonomous flight management systems, along with the necessary support services to assist with system integration, which facilitate the transformation of manned aircraft into entirely autonomous UAVs. These UAVs could be subsequently armed and launched from hidden locations close to their intended targets. No effective MTCR restrictions—not even case-by-case reviews of exports—currently exist to manage the acquisition of these products and services. The MTCR should take urgent steps to agree appropriate language changes to Category II, Item 10 controls on such flight management systems. Any amendment must capture all such systems usable in, not just specifically designed for, controlled UAVs.

Tighter controls on stealthy cruise missiles and specially designed and related countermeasures equipment are also needed. There have been numerous calls for controls on stealthy cruise missiles, but participants in the MTCR

[63] Dr Gregory DeSantis, a private consultant, arrived at this estimate using Internet searches of the literature on kit aircraft. Private communication with the author, 1 Feb. 2002.

[64] For growing concern about terrorist use of light aircraft, of which there are reportedly 'tens of thousands' in the USA, see Miller, L., 'Small airports are a security concern', Associated Press, 6 Jan. 2003, URL <http://www.washingtonpost.com/wp-dyn/articles/A18728-2003Jan6.html>.

have struggled to reach consensus on precisely what level of control to impose. The best approach would be to subject those missiles with a range of over 300 km, regardless of payload—currently covered by Category II, Item 19—to the same presumption of denial as Category I systems. These missiles do not need 500-kg payloads to achieve mass effects. Substantially smaller payloads of biological agent, stealthily delivered, would produce the kind of shock effects and present the same defence difficulties that originally informed the creation of MTCR controls on ballistic missiles carrying nuclear payloads. Specially designed countermeasure equipment, such as towed decoys or terrain bounce jammers, is organically related to the performance of stealthy cruise missiles.[65] The effectiveness of these subsystems increases as the radar cross sections of cruise missiles reduce. Thus, as such equipment is paired with stealthy cruise missiles, it renders existing defences (and even future, more advanced, systems) problematic. Since such countermeasure equipment can generally be used to enhance manned aircraft survivability, it would apparently be exempted under Category II controls. However, to achieve its intended synergistic effect with stealthy cruise missiles, it must be specially designed or modified to fit the companion missile. This suggests that the equipment could be captured under the MTCR's Category II controls without prejudicing manned aircraft protection.

Commercial and military jet engines, capable of slightly more than 2000 pounds of thrust (*c.* 900-kg thrust), are also worthy of case-by-case review before export. They are fully usable in cruise missile development or conversion programmes. Broadening the regime's parameters under Category II, Item 3 would impose only a slight burden on export control authorities—to review licensing applications commonly used in manned aircraft.

To make the MTCR capable of handling rapid changes in technology, there is an urgent need to comprehensively assess the impact of unarmed UAVs, UCAVs and LTA systems on existing MTCR controls. As the USA has demonstrated, unarmed UAVs can be adapted to carry substantial weapons payloads over strategically significant distances. Because precise data on the true one-way range and payload potential of unarmed UAVs are not readily available, new methodologies will be needed to make such determinations. The fact that nearly 80 per cent of the sample of over 600 UAVs cited at the start of this chapter appear capable of exceeding the MTCR's 300 km-range threshold suggests that participants must practice an extraordinary degree of vigilance and informed judgement when specifying which UAVs should be subject to MTCR controls.

As for how, and indeed whether, certain anomalous classes of unmanned systems—namely, unmanned LTA craft and UCAVs—are treated, much work remains to be done. In theory, LTA craft are treated as MTCR-controlled delivery systems, despite the fact that their utility for WMD delivery is dubi-

[65] Towed decoys are radar transmitters that are towed behind an aircraft by means of a cable. Terrain bounce jammers, carried on low-flying aircraft, pick up a missile seeker's signal, amplify it and retransmit it back to the ground. The seeker, presented with a choice between a weak echo from the skin of the missile and a bright mirror image on the ground, homes in on the spot on the ground.

ous. In fact, they have an enormously valuable role to play in detecting and tracking offshore cruise missile threats.[66] UCAVs would also be used in a military role not unlike that of manned aircraft, yet they are MTCR-controlled systems. Participants should immediately request that their technical advisers undertake an investigation leading to recommendations that redirect MTCR controls towards the types of UAVs that pose the greatest proliferation threats. This should not preclude the possibility that some UAVs could be removed from MTCR controls.[67]

V. Conclusions

Because of their capacity to strike with such great precision and effectiveness without causing significant collateral damage, Lawrence Freedman has called cruise missiles 'the paradigmatic weapon of the RMA' (Revolution in Military Affairs).[68] This chapter has assessed the crucial companion roles that UAVs, unarmed and armed, have started to play as key instruments of an evolving military transformation in the USA. However, just as much risk as opportunity accompanies the arrival of cruise missiles and UAVs as powerful military instruments. The spread of these systems globally will affect US military dominance, regional stability and homeland defence.[69] As a consequence, the growing threat of cruise missiles and UAVs underscores the need not just to develop suitable defences but also improved non-proliferation policies.

The non-proliferation problems discussed in this chapter are certainly challenging. They merit the highest level of attention within affected governments. Because existing MTCR provisions can be adapted to achieve better controls on cruise missiles and UAVs, the MTCR will remain the best tool available to slow the scope and pace of missile proliferation. In considering the merits of various alternatives to the MTCR, the non-proliferation community should recall the MTCR's many successes in slowing the qualitative spread of ballistic missiles. They are not only a potent reminder that the best can frequently become the enemy of the good, but an urgent call to address the next great missile proliferation threat through more effective controls on cruise missiles and UAVs.

[66] Wall, R., 'Interest balloons in military blimps', *Aviation Week & Space Technology*, 11 Nov. 2002, pp. 55–56.

[67] The author is grateful to Dr Richard Speier for these suggestions. Interview by the author, 3 Jan. 2003.

[68] Freedman, L., *The Revolution in Strategic Affairs,* Adelphi Paper 318 (Oxford University Press, Oxford: London, 1998), p. 70.

[69] Third country intelligence sources reported that Iraq was developing a small, easily transportable UAV capable of being shipped into the USA or built there and used for a chemical or biological attack. Cloud, D. and Robbins, C., 'At Davos, Powell pushes back against resistance over Iraq', *Wall Street Journal,* 11 Jan. 2003, p. 1.