Biosecurity and the Governance of Science

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Abstract

Many of the technologies required to produce biological weapons also have legitimate peaceful applications. This ‘dual use’ phenomenon creates a dilemma for science policy as attempts to control the generation, diffusion and application of these technologies for prohibited purposes can have unintended impacts on their socially beneficial uses. This paper explores how concerns about biosecurity are changing the governance of technology in general and scientific research in particular. It assesses the relative merits of framing dual use policy in terms of either technology transfer or technology convergence and highlights both the benefits and problems associated with policies directed at purposes rather than things.

Introduction

The aim of this paper is to contribute towards the practical development of governance measures that address the ‘dual use’ nature of scientific research. It does so by exploring the relative merits of different ways of understanding the controls which are being introduced to prevent the proliferation of technological capabilities related to the development and production of biological weapons as defined in the 1972 Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction (BWC). Within the paper ‘dual use’ refers to the tangible and intangible features of technologies that enable them to be applied to both (illegal) hostile and peaceful ends with few or no modifications (Molas-Gallart and Robinson, 1997). As such, the term highlights how the same upstream activities, materials, information and equipment can potentially have both hostile and peaceful applications downstream.

When the term ‘dual use’ first entered the technology policy literature, its conventional employment relayed positive connotations related to the benefits a nation could generate from exploiting civilian technologies to develop and produce military technologies (Alic, et. al. 1992; Alic, 1993; Reppy, 1999; Molas-Gallart, 2000, 2002; on technology transfer more generally see Bozeman, 2000). Since the late
1970s, however the term ‘dual use’ has begun to take on a significantly more negative connotation and is used to address the potential of technologies with legitimate civilian uses to aid the proliferation of prohibited military technologies (Roberts, 1995; United Nations General Assembly, 1977; see Molas-Gallart, 1996, p. 6). In particular, the term is being increasingly applied to technologies with legitimate application in scientific research, drug and vaccine production, agriculture and industrial processing that could also be misappropriated to produce chemical or biological weapons (McLeish, 2002).

Although it has been recognised since at least the 17th century that the same technology can produce both beneficial and harmful outcomes (Bacon 1609), and the term is well used within the arms control and disarmament communities, the science policy issues generated by the issue of dual use in this second, negative sense, have become increasingly apparent as appreciation of the threat posed by biological weapons, and its links to the life sciences, has widened. This potential dual use nature of life science research achieved very public prominence after the publication of three papers: one on the synthesis of polio virus cDNA without a natural template by Cello et al (2002); another providing information on how the variola virus (smallpox) can evade the immune system by Rosengard et al (2002); and a third on how to overcome genetic resistance to mouse-pox by Jackson et al (2001). These papers were interpreted as “publishing a blueprint” for terrorists to inflict mass destruction and led to public calls for changes to research practice and scientific publication (Wallerstein, 2002; Cozzavelli, 2003; Malakoff, 2003; Purver, 2002; Danchin, 2002; Finkel, 2001; Kahn, 2004).

This overlap between science and security policy is part of a wider policy drive related to biological weapons that has escalated since the international negotiations to strengthen the BWC failed in July 2001 and the posting of letters laced with anthrax in the US in the Autumn of 2001. As a consequence of events such as these, the historically close relationship between the life sciences and biological weapons development (Guillemin, 2004; Fraser and Dando, 2001; Leitenberg, 2001) has been recast as one of the most significant policy issue of the day (Martin, 2002). Framings of the threat posed by biological weapons which have been issued since 2001 have, for example, suggested that advances in the life sciences and the spread of biotechnology through legitimate activities are increasing the perceived levels of threat (and therefore the perceived vulnerability of society) by increasing the number of actors who have access to the relevant biological warfare (BW) technologies. This, in turn, has led to a range of policy measures being initiated that are directly affecting the practice and governance of science (NRC 2004; Gaudioso and Salerno 2004; Atlas 2002)

3 See for example, Representative Dave Weldon (R-FL) House Resolution 514, in response to the publication of the polio synthesis paper in *Science*. (July 26th 2002 House of Representatives, 107th Congress). However, the Fink Report noted that this method had been in principle available since 1981, was extremely labourious, and was scientifically interesting precisely because of the weakened pathogenicity compared to the wild-type virus (NRC 2004:22).

4 For example, traditionally many scientific journals in the biological sciences require authors to provide their research materials on request as a condition of publication. Such actions might now be subject to national and international legal restraints (Danchin 2002; Breithaupt 2000; see also Musser (2001) on chemistry)
biosecurity related research. Since 2001 the funding for bio-defence research at the National Institutes of Health (NIH) has increased by 3,200% (Harris and Steinbruner, 2005:1).5

The characteristic of ‘dual use’ shapes policies which aim to reduce the threat posed by biological by focusing attention on the diffusion of economically beneficial technologies often owned and traded by non-state actors, rather than just weapons. Dual use also makes the design and implementation of effective solutions problematic, because policies designed to constrain the acquisition and exploitation of technologies for activities prohibited by international treaties such as the BWC can also potentially disrupt legitimate scientific and technical activity, with corresponding and potentially substantial social costs (McLeish and Nightingale 2005; NRC2004; Gaudioso and Salerno 2004; NRC, 2004; Science 2002; Atlas, 2001, 2002; Robinson 1997; NAS 1982; Breithaupt, 2000). Their global spread for legitimate uses through these legitimate channels is widely regarded as something that should be encouraged rather than hindered, so the dilemma created for both the security and scientific policy communities is how to design policies which successfully suppresses biological weapons development whilst accommodating, and even encouraging, the proliferation of these legitimate technology development and research activities.

This paper aims to assist policymaking in a) science policy by outlining how biosecurity concerns are changing the governance of research (and other activities) in the life sciences, and b) security policy by evaluating the advantages and disadvantages of framing the dual use problem as a technology transfer or technology convergence problem.6 In doing so, the paper draws on regime theory within security studies (Müller 1995; Krasner 1983), the technology governance literature (e.g. Braithwaite and Drahos 2000) and the science policy literature on the relationship between artefacts and their functions (Rosenberg, 1963; Nightingale 2004).

The paper is divided into a further three sections. Section 2 explores recent policy measures that have been introduced by traditional and non-traditional security actors (such as states and the scientific community) to govern research and development. Section 3 addresses the main concern of this paper: how these

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5 In US total National Institutes of Health (NIH) funding for biodefence has increased from $25m in FY 2001, to a peak at $1748m in FY 2003 before falling slightly to $1600m in 2004 (Fauci, 2005; Harris and Steinbruner, 2005). The extent of this increase can be seen by comparing it to the approximately $500m total research funding of the UK Medical Research Council (2004). The majority of the monies awarded to NIH in 2003 went to the National Institute of Allergy and Infectious Diseases (NIAID) where 50 biodfence initiatives were developed in fiscal years 2002 and 2003. Changes in NIH funding and priorities have lead to the construction of a series of National Biocontainment Laboratories built to Biosafety Level 4 standards, together with nine Regional Biocontainment Laboratories with Biosafety Level 3 facilities. NIAID has also funded eight Regional Centres of Excellence for Biodefense and Emerging Infectious Diseases Research (Fauci, 2005). It is argued that these increases have shifted the direction of life science research towards pathogens with potential hostile use. The number of grants awarded for research on BW agents has risen 1,500% from “33 between 1996-2000, to almost 500 between 2001 and January 2005” (Harris and Steinbruner, 2005:1). As a result more than 300 institutes and 12,000 individuals in the US now have access to pathogens historically associated with bioweapons (Schwellenback, 2005). Furthermore, analysis of the principal investigators of NIAID grants between 2001 and 2005 to study the six priority biodefence pathogens suggests that 97% of them are new to the field (ibid).

6 All the changes discussed in the paper come under an overarching bio-security umbrella, but cover distinct areas: bio-terrorism (the threat or use of disease by non-state actors for political ends); bio-defence (the development of responses to biological warfare attack, including bioterrorism); dual-use controls (controls on technologies with legitimate and prohibited applications) and non-proliferation (controls on the diffusion of technologies to prevent their (illegal) hostile use).
changes should be understood. It examines how framing the dual use problem in its current terms (i.e. as a problem of technology transfer) generates policies directed at artefacts that aim to prevent the transfers of dangerous technologies from science. An alternative framework is then presented which frames the dual use problem as one of technological convergence. This framework generates policies directed at purposes, rather than things, and which would aim to disrupt innovation processes including addressing the role of wider bodies of knowledge and infrastructures in generating prohibited technologies. This alternative understanding (1) permits a more subtle analysis of the complex interactions between scientific research and technological development, (2) provides some guidance to risk analysis by highlighting the substantial differences between (so called) ‘dangerous’ science, weapons and weapons of mass destruction and (3) by emphasising purposes not things helps prevent present and future policy solutions from being locked into definitions which could become overtaken by scientific and technological change. Section 4 addresses science policy implications.

Section 2: An overview of the biological weapons problem

The policy problem associated with biological weapons is not a traditional security problem which deals with ‘disarmament’ or ‘arms control’ as these terms are normally understood because use of the biological weapons are prohibited to all states through ancient norms embodied in customary international law and by an historically very successful treaty regime. The biological weapons policy problem therefore:

“has no connection to the problems under the [Nuclear Non Proliferation Treaty] related to discrimination between different categories of states; it is not about attempting to achieve disarmament because no state under the BWC is permitted to have biological weapons; it has no connection to oversight of destruction of tens of thousands of chemical weapons within six states (Albania, India, Libya, Republic of Korea, Russia, US) under the 1993 Chemical Weapons Convention” (Littlewood, 2004:3)

Instead the policy problem concerns the maintenance of respect for the international law that already exists, in other words with preventing the use of disease for hostile purposes.

With the end of the Cold War and the resulting disruption to the post-World War 2 balance of power, the security policy agenda refocused and intergovernmental bodies such as the United Nations began to redefine the threats to international peace and security. One such redefinition came at the January 1992 summit session of the United Nations Security Council where weapons of mass destruction where highlighted as the greatest threat to international peace and the participating heads of state and governments outlined a course of action involving “the members of the Council comit[ing]] themselves to working to prevent the spread of technology related to the research for or production of such weapons and to take appropriate action to that end” (emphasis added, UNSC, 1992). As a result, the governance of scientific fields related to weapons of mass destruction (biology, chemistry, physics etc) was explicitly stated to be within the remit of security policy thereby also making technology governance a central part of post Cold-War security.
Security policy has continued to focus on technological diffusion, particularly the proliferation of dual use technologies and their potential to be applied to weapons development. The Final Declaration of the Fourth BWC Review Conference in 1996, for example, specifically highlighted the problem of dual use technologies and noted their increased concerns about advances in relevant scientific fields which might also be applied to biological weapons development. In particular they noted advances in ‘microbiology, biotechnology, molecular biology, genetic engineering, and any applications resulting from genome studies’ (Fourth Review, 1996). Five years later at the next Review Conference, the UK delegation submitted a detailed science and technology review which highlighted the ‘great advance in a number of fields which provide understanding of the genetic, structural and functional basis of micro-organisms and toxins, and in the number and sophistication of techniques able to make directed changes to the properties of micro-organisms or toxins.’ (UK 2001). The review contained detailed sections under headings such as genomics and proteomics; bioinformatics; gene therapy; virulence and pathogenicity; vaccines and novel therapies; recombinant protein expression; toxins and other bioactive molecules; drug resistance; disease in agriculture; pest control in agriculture; molecular biology applications and crops; trends in protein production technologies (ibid). At the same conference, the American delegation also highlighted ‘major advances have occurred in the fields of genetic modification, genomics, proteomics, bioremediation, bio-control agents, vaccine development and bioinformatics [and that] of special interest to the BWC are applications in directed molecular evolution (i.e. genetic modification, proteomics, bioinformatics and vaccinology’ (USA, 2001).

Following the failure of the attempts to strengthen the BWC in 2001, a new ‘intersessional process’ of annual talks among BWC States parties has shifted attention towards new national and multinational measures which increasingly address the practice of science as part of a wider regime of measures. These measures include a shift towards implementing bio-safety guidelines, regulating access to pathogens, reporting disease outbreaks and developing ethical codes of conduct. This new emphasis has resulted in the issue of dual use research and technology becoming entrenched within security policy, and is why security policy and science policy are increasingly overlapping.

Some measures highlighting this trend are briefly reviewed below.

**Multilateral controls**

The ‘regime’ addressing the hostile use of disease comprises a collection of cooperative and coercive national and international control measures – including international agreements, multinational organizations, national and international laws, regulations, policies, norms and rules – intended to prevent

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7 They went on to note the dual use potential of these sciences:

“While offering obvious benefits to mankind, advances in technology can be used to produce new substances or modify old ones and lead to novel and significant toxins and biological and biochemical weapons threats. Nations should remain cognizant of and carefully monitor for potential abuse of these evolving technologies’ (ibid).
the spread of dangerous weapons and technologies. The normative backbone of the regime (Hasenclever et al 1997) is the 1972 *Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction* (BWC) which sets out, and clearly establishes what is and what is not legitimate behaviour through a framework of rules and norms. Membership of this multilateral treaty currently stands at 155 with an additional 16 signatory states. Under the this Convention, State parties are “determined, for the sake of all mankind, to exclude completely the possibility of bacteriological (biological) agents and toxins being used as weapons” to which end they obligate themselves:

never in any circumstances to develop, produce, stockpile, or otherwise acquire or retain:

1. Microbial or other biological agents or toxins whatever their origin or method of production of types and in quantities that have no justification for prophylactic, protective or other peaceful purposes;

2. Weapons equipment or means of delivery designed to use such agents or toxins for hostile purposes or in armed conflict [emphasis added]

The treaty therefore covers all phases of the armament process except research, including development, production, stockpiling and acquisition of the necessary agents and delivery equipment needed to produce a weapon. This article also recognizes, in the words underlined, the dual use problem. Known as the General Purpose Criterion these underlined words define the scope of the treaty whereby purposes rather than things are prohibited. In doing so the words prevent the treaty from being overtaken by future developments in science and technology because all purposes other than “peaceful purposes” are prohibited: consequently the BWC covers any future forms of hostile use and therefore codifies against the hostile use of disease in a timeless fashion.

As well as eschewing biological armament, members of the BWC also obligate themselves not to assist, encourage or induce any State, group of States or international organizations to do the same. As with other treaties, these international rules and obligations are operationalised via the implementation of national

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8 *State Parties To The Convention On The Prohibition Of The Development, Production And Stockpiling Of Bacteriological (Biological) And Toxin Weapons And On Their Destruction*, List prepared for Meeting of the States parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, 21 June 2005, BWC/MSP/2005/MX/INF.5

9 While it does not directly address use, the 1925 *Protocol for the prohibition of the use in war of asphyxiating, poisonous or other gases, and of bacteriological methods of warfare* (more commonly known as The Geneva Protocol) is widely accepted to have achieved the status of customary international law (Greenwood, 2000:802-805) and prohibits states use of biological weapons. The prohibition against use was reaffirmed in the final document of the BWC’s Fourth Review Conference in 1996 (see Fourth Review Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, *Final Document*, Geneva, 25 November-6 December 1996, BWC/CONF.IV/9)

10 Rapid changes in technology create the danger that the letter of the law will become obsolete and be unable to cover developments addressed by the spirit of the law. A similar problem faced the 1923 *Hague Draft Rules on Aerial Warfare*, which attempted to define legitimate military targets using lists, but was unable to keep up with the increasing numbers of military targets generated by changes in technology. As a result of this failure, more flexible approach that address purposes rather than things have been introduced. Additional Protocol I, Article 52(2) now limits military objectives to ‘those objects which by their nature, location, purpose or use make an effective contribution to military action and those total or partial destruction, capture or neutralisation, in the circumstances ruling at the time, offers a definite military advantage.’ (Greenwood, 2000:797, emphasis added).
laws and regulations. Thus to prevent individuals from performing the actions it prohibits to states, the BWC requires its parties to take any necessary measures to prohibit and prevent the development, production, stockpiling, acquisition or retention of the agents, toxins, weapons, equipment and means of delivery specified in article I of the Convention, within the territory of such State, under its jurisdiction or under its control anywhere (Article 4).

In the United Kingdom for example the *Biological Weapons Act* (1974) implements the prohibitions of the BWC and makes it a criminal offence for a UK national to develop produce stockpile acquire or retain any biological agent or toxin of a type and in a quantity that has no justification for prophylactic, protective or other peaceful purposes and any weapon, equipment or means of delivery designed to use biological agents or toxins for hostile purposes or in armed conflict. These prohibitions and criminal offences were extended under the *Anti Terrorism Crime and Security Act*, (2001) by making it a further criminal offence to transfer or make arrangements to transfer the necessary materials if the purpose is likely to be other than those allowed. The Act also extended jurisdiction to acts committed outside the UK by UK nationals. And when the BWC was implemented nationally in the USA through the *Biological Weapons Act* (1989) it became a criminal offence, with extraterritorial Federal jurisdiction when committed by or against a U.S. national, to produce, develop, transfer, acquire, retain, or possess any “biological agent, toxin, or delivery system for use as a weapon” or provide aid to anyone doing so. The *Antiterrorism and Effective Death Penalty Act* (1996) further extended this offence by criminalizing the threat to use biological weapons.

**Additional policy measures**

Although the BWC is comprehensive in its coverage of the full spectrum of risk (state use, terrorist use and criminal use) it is recognized that there is “no one size fits all” policy solution to the problem posed by biological weapons in general, and by the proliferation of dual use technologies in particular (Littlewood 2004, 2005; Chyba and Greninger 2004). As a result, a number of additional policy measures also designed to prevent the use of disease for hostile purposes have been introduced, some of which address the practice and governance of scientific activities. Because biological weapons are outlawed by international law, these additional policies focus on the governance of the technology underlying the weapons rather than the weapons themselves.\(^{11}\) However, the technologies necessary for the development of weapons – including a biological agent, methods to cultivate the agent, a means of delivery etc – typically also have legitimate peaceful applications and so cannot be easily banned outright.

One way in which states have tried to overcome this dilemma and promote the diffusion of dual use technologies for legitimate purposes, while suppressing their diversion to weapons purposes, has been through supply side technology controls such as export controls. These measures place roadblocks in the technology acquisition process by disrupting the flow of technology (Defense Science Board, 2000).

\(^{11}\) ‘Underlying technologies’ are understood to include intangibles, artefacts, socio-technical systems and their technological regimes (see Freeman and Soete, 1997).
Export controls are based on understanding the dual use problem in terms of technology transfer and rely on judgements about the intent of the requesting party so that technology is transferred only to recipients that the exporting state judges not to present cause for concern.

The recent history of controlling flows of technology for security reasons can be traced to the Cold War period. The Australia Group, for example, was set up in 1984/5 in response to evidence that Iraq had sourced some of the precursor chemicals and materials for its chemical warfare program through legitimate trade channels (Robinson, 1992; Zilinskas, 1999). Specifically dedicated to reducing the likelihood that legitimately traded chemical technologies (and later biological technologies) might be misused the aim of the Australia Group is to “limit the risks of proliferation and terrorism involving chemical and biological weapons by controlling transfers of technology that could contribute to chemical and/or biological weapons activities by states or non-state actors”. This is done through the use of harmonized export controls whereby members of the Australia Group agree to use licensing measures to ensure that exports of certain chemicals, biological agents, plant and animal pathogens, as well as certain chemical and biological equipment and related dual use technologies do not contribute to the spread of chemical and/or biological weapons. These broad categories form the basis of the Group’s common control lists, which are reviewed and updated when necessary to take account of scientific and technological advances. A ‘catch-all’ clause also ensures that the Australia Group provisions remain technologically relevant and free from capture.

The lists devised by the participating Australia Group countries are comprehensive – for example the dual use biological equipment list covers common technologies such as certain types of fermentors, centrifugal separators, freeze drying equipment as well as certain types of aerosol inhalation chambers. The biological agent list is equally broad – the core list currently includes 32 viruses; 4 rickettsiae; 15 bacteria and 19 toxins and subunits thereof. The list also covers genetic elements and genetically modified organisms associated with the agents on the list except when they are in the form of a vaccine.

Another international export control regime, the 1993 Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies became the first post-Cold War export control regime which covers exports of conventional weapons systems and weapons of mass destruction and their delivery systems. It pursues its nonproliferation objectives by promoting transparency, exchange of views and information on transfers of conventional arms and dual-use goods and technologies so they do not

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12 Export controls existed before the Cold War. For example, in the UK The Import, Export and Customs Powers (Defence) Act was passed in 1939. For half a century the emergency wartime powers granted by that Act were used to control UK imports and exports. A short amending Act - the Import and Export Control Act, 1990 - was put through Parliament in November and December 1990. The amending Act removed a section of the 1939 Act, which provided for expiry on the making of an Order declaring the ‘emergency’ to be over.


14 See http://www.australiagroup.net/en/agact.htm

15 As with the Wassenaar Agreement though, the controls on ‘technology’ transfer do not apply to information ‘in the public domain’ or to ‘basic scientific research’ or the minimum necessary information for patent application. http://www.australiagroup.net/en/control_list/bio_agents.htm
contribute to the development or enhancement of military capabilities that undermine international and regional security.\textsuperscript{16}

Defining technology as

Specific information necessary for the ‘development’, ‘production’ or ‘use’ of a product. The information takes the form of technical data or technical assistance…\textsuperscript{17}

The Wassenaar arrangement goes on to note that ‘technical data’ may take forms such as blueprints, plans, diagrams, models, formulae, tables, engineering designs and specifications, manuals and instructions written or recorded on other media or devices such as disk, tape, read-only memories and that ‘technical assistance’ may take forms such as instruction, skills, training, working knowledge, consulting services (ibid). The controls however do not apply to ‘technology’ ‘in the public domain’, to ‘basic scientific research’ or ‘to the minimum necessary information for patent applications’.

As the above definitions imply, the Wassenaar Agreement covers both tangible and intangible technology transfers. For tangible technology transfers, the participating states agree a list of technologies\textsuperscript{18}, on which they must place effective export controls. This agreed list includes targeting dual use goods and technologies “which are major or key elements for the indigenous development, production, use or enhancement of military capabilities”.\textsuperscript{19} This list is regularly reviewed and updated to take into consideration scientific and technological advances as well as experience of transfers.

In 2000, participating states agreed that intangible technology transfers needed to be part of an effective export control regime and agreed that mutual exchange of experiences gained from implementing and enforcing national controls was necessary. Particularly emphasized in their understanding of intangible technologies is software and other forms of technology related to conventional weapons and dual-use items and intangible means of transfer e.g. oral transfers, or transfers by fax email or telephone.\textsuperscript{20}

\textsuperscript{16} The Arrangement is open on a global and non-discriminatory basis to prospective adherents that comply with the agreed criteria. To be admitted, a state must: be a producer/exporter of arms or industrial equipment; maintain non-proliferation policies and what are judged to be appropriate national policies, including adherence to relevant non-proliferation regimes and treaties; and maintain fully effective export controls.

\textsuperscript{17} ‘In the public domain’ is defined as ‘“technology’ or ‘software’ which has been made available without restrictions upon its further dissemination”; and ‘basic scientific research’ is taken to mean “experimental or theoretical work undertaken principally to acquire new knowledge of the fundamental principles of phenomena or observable facts, not primarily directed towards a specific practical aim or objective”. See http://www.wassenaar.org/controllists/16%20-%20WA-LIST%20%2804%29%20DEF.doc; http://www.wassenaar.org/publicdocuments/Basic%20documents%20September.doc

\textsuperscript{18} http://www.wassenaar.org/list/wa-listTableOfContents.htm

\textsuperscript{19} Wassenaar Agreement. \textit{Criteria for the selection of dual-use items}, as agreed December 2004 See http://www.wassenaar.org/list/Criteria%20for%20DU%20List%20including%20SL%20and%20VSL%20for%20WEB%20Site.doc

\textsuperscript{20} Previous efforts had been made at the national level to implement legislation on the transfer of intangible technologies - for example on 10th March 1993 the UK the Foreign and Commonwealth Office convened a large ‘awareness raising seminar’ principally for people involved in biotechnological research and industry. Although its primary purpose was to explain the government's new export controls aimed at preventing the proliferation of biological weapons and to launch a BW Awareness Raising Booklet the idea was floated of the government vetting university intakes of overseas students as means for controlling transfer of ‘intangible technology’. (Wilkie, 1993, p 1.) A year later, in 1994, the voluntary vetting scheme (VVS) was launched. Administered by the Foreign and
Outside of export controls, other policy solutions have been adopted to govern mainly tangible technology transfers of dual use technologies. The rise of the “proliferation-terrorism nexus” (Ellis 2003) for example has caused states to implement national and international policy solutions which go beyond these traditional policy options and offer more dynamic and active solutions to the proliferation of dual use materials associated with all weapons of mass destruction, including biological weapons.

The Proliferation Security Initiative (PSI) launched in 2004, is one such dynamic measure. Supported by over 60 countries PSI aims to counter the development of WMD by all non-state actors (such as terrorists) and states of concern, together with those who supply such programmes through trafficking in sensitive materials, equipment and technology (Byers 2004, Joyner 2004). PSI participants commit to following interdiction principles to impede or stop threatening shipments of WMD and missile related equipment and technologies and aims to impose these obligations on all states, including those approximately 40 states that are not yet signatories of the BWC and thus are not yet obliged to have national laws in place that implement the BWC prohibitions. Similarly, UN Security Council Resolution 1540 (2004) is a dynamic measure obligating all UN member states to refrain from providing any form of support to non-state actors attempting to acquire, use or transfer WMD and their delivery systems, and that in accordance ‘their national procedures, shall adopt and enforce appropriate effective laws which prohibit any non-State actor to manufacture, acquire, possess, develop, transport, transfer or use nuclear, chemical or biological weapons and their means of delivery, in particular for terrorist purposes’ (see UN 2004, Oosthuizen and Wilmshurst 2004, Kellman 2004).

UNSC Resolution 1540 addresses non-state threats, including the transfers of dual use technologies, by obligating states to adopt and enforce appropriate and effective national laws. However national criminal legislation is not a substitute for international legal measures. As well as problems of harmonising various provisions regarding the definition of crimes, the rights of the accused, judicial assistance etc, purely national criminal statutes do not convey the universal condemnation implicit in international criminal law. As such other proposals have been made which seek to define specific acts involving biological and chemical weapons (including the transfer of dual use material) as international crimes. A draft convention to prohibit biological and chemical weapons under international criminal law, for example, has been proposed by the Harvard Sussex Program on Chemical and Biological Weapons. Adoption of this convention would create a new dimension of constraint against biological and chemical weapons by Commonwealth Office, the scheme was later described as expressly set up to “stop individuals from certain countries which we regard as proliferators or potential proliferators of WMD from taking courses which would help them acquire the knowledge necessary to assist with the production or manufacture (proliferation) of WMD within their home country and which might one day threaten the UK’s national security” (emphasis added <www.fco.gov.uk/Files/kfile/VVS.doc>) Other efforts have also been made by the UK government to address the intangible element of technology within its legal definitions, including most recently the Export Control Act (2002) and Export of Goods, Transfer of Technology and Provision of Technical Assistance (Control) Order (2003) where ‘technology’ is defined as including ‘information (including but not limited to information comprised in software and documents such as blueprints, manuals, diagrams and designs) that is capable of use in connection with the development, production or use of any (prohibited) goods’. For more on VVS see ‘Dr Howells for the Secretary of State for Education and Employment to Mr. Brake’ Hansard (Commons), written answers, vol 307, 25 February 1997, col 295, <http://www.publications.parliament.uk/pa/cm200203/cmselect/cmsctech/415/415ap56.htm>
holding individual offenders (regarded under the Convention as *hostes humani generis* – enemies of all humanity) responsible and punishable should they be found on the territory of any State that supports the Convention. (Meselson and Robinson, 2002).

**National Measures**

National controls other than export control regulations are also used to govern dual use technology transfers and have been the main vehicles by which scientific activity is governed both in terms of what can be done and who can do it (Kellman, 2001). For example, national controls have been developed for specific lists of biological agents and measures to also developed to consider transfers of them within and across national boarders. Such controls implement rules over and above those normally required by health and safety regulations.

In the US controls have been developed whereby additional obligations are placed on certain ‘select agents’, defined as “biological agents or toxins deemed a threat to the public, animal or plant health, or to animal or plant products”. The list of select agents currently includes 33 viruses; 1 prion; 11 toxins; 19 bacterium and 6 fungi.\(^{21}\) Also covered by the list are genetic elements, recombinant nucleic acids and recombinant organisms associated with the select agents as well as two types of experiments which involves the deliberate transfer of a drug resistance trait to a listed agent and the deliberate formation of recombinant DNA containing genes for the biosynthesis of certain listed toxins.

The *Uniting and Strengthening America by Providing Appropriate Tools Required to Intercept and Obstruct Terrorism (USA Patriot) Act*, 2001 complements and reinforces the security aspect of the select agent controls by requiring that ‘no restricted person’ shall possess, transport or receive any biological agents or toxins listed in the Act as select agents.\(^{22}\) Before working with or having access to any select agent the *Public Health Security and Bioterrorism Preparedness and Response Act*, 2002 requires that all those wishing to possess, use, or transfer such agents and toxins, undergo registration to ensure that they

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\(^{21}\) As of November 2005

\(^{22}\) ‘Restricted persons’ are defined by the act as an individual who:

- Is under indictment for a crime punishable by imprisonment for a term exceeding 1 year;
- Has been convicted in any court of a crime punishable by imprisonment for a term exceeding 1 year;
- Is a fugitive from justice;
- Is an unlawful user of any controlled substance (as defined in section 102 of the Controlled Substances Act (21 U.S.C. 802));
- Is an alien illegally or unlawfully in the United States;
- Has been adjudicated as a mental defective or has been committed to any mental institution;
- Is an alien (other than an alien lawfully admitted for permanent residence) who is a national of a country as to which the Secretary of State… has made a determination (that remains in effect) that such country has repeatedly provided support for acts of international terrorism; or
- Has been discharged from the Armed Services of the United States under dishonorable conditions.

are permitted to perform those activities – i.e. that they are not restricted persons.\textsuperscript{23} This includes undergoing a security risk assessment (including fingerprinting) by the FBI and then being granted approval (based on that security risk assessment) by either the Centers for Disease Control and Prevention (CDC) or the US Department of Agriculture's Animal and Plant Health Inspection Service (APHIS), before even gaining access to select agents or toxins. This security risk assessment is valid for three years and subject to CDC or APHIS termination. The Act also requires the Secretary of Health and Human Services to maintain a national database of individuals and the select agents they have access to.

The UK has a similar select agent list which can be found in the \textit{Anti Terrorism Crime and Security Act}, 2001. The list developed there under Schedule 5 places additional obligations over and above those found in UK health and safety regulations. Currently the list contains 19 viruses, 5 rickettsiae, 13 bacteria, 11 toxins and includes genetic material associated with any one of the agents or genetically modified organisms containing a sequence of a listed agent. Legal obligations are placed on the occupier of any premises to notify the Secretary of State before any dangerous substance is kept or used there.\textsuperscript{24} Should it be deemed necessary, the occupier of the premises is obligated to release this information to a senior police officer who may give the occupier of any relevant premises a notice requiring them to provide a list of each person who has access to any dangerous substance kept or used there or who has access to premises.\textsuperscript{25}

Should the Secretary of State have reasonable grounds for believing that adequate measures to ensure the security of any dangerous substance kept or used in any relevant premises are not being taken and are unlikely to be taken, he may give a direction to the occupier of the premises requiring him to dispose of the substance. Furthermore the Secretary of State may give directions to the occupier of any relevant premises requiring him to prevent an individual from having access to any dangerous substance kept or used there and/or if necessary prevent access to such parts of the premises as the Secretary of State directs.\textsuperscript{26} For an initial assessment of the impact of these measures see McLeish (2004).

\textbf{Other Governance Measures Covering Scientists}

The increasing global diffusion of biological technologies is a significant complicating factor in attempts to control transfers of dual use BW technologies. Historically, the only actors considered able to afford the costs of developing biological weapons were states (Koblentz 2003, Guillemin 2004) but the globalization of dual-use biological technologies through legitimate activities has altered this perception and


\textsuperscript{24} Paragraph 59 “Duty to notify Secretary of State before keeping or using dangerous substances”, Part 7 Security of Pathogens and Toxins, \textit{Anti Terrorism Crime and Security Act}, 2001.


\textsuperscript{26} Paragraph 63 “Directions requiring disposal of dangerous substances” and Paragraph 64 “Directions requiring denial of access” Part 7 Security of Pathogens and Toxins, \textit{Anti Terrorism Crime and Security Act}, 2001.
consequently required governments to increasingly seek to enroll actors not normally associated with security in their efforts to reduce the threat.

Recent measures advanced by both the security and scientific policy communities typically focus on constraining the actions of states and terrorist by denying them access to certain tangible and intangible technologies. These take the form of further controls on people, the flow of information and the performance of certain experiments.

A vetting scheme for students wishing to study certain ‘dual use’ degree subjects, for example, operates in both the UK and the USA. The voluntary scheme in the UK, which began in 1994, was described as necessary after it became apparent that a number of state proliferators had used the UK to train their weapons’ scientists so a system was developed to frustrate attempts to use UK universities as training grounds. Administered by the Foreign and Commonwealth Office (FCO), the scheme applies to postgraduate students and post-doctoral researchers from certain countries and covers those scientific disciplines deemed relevant to weapons of mass destruction or the missiles to deliver them. Under the scheme, universities and higher education colleges are able, on a voluntary basis, to seek advice from the government about whether an application from a potential student from a listed country who is seeking to undertake research in a particular discipline should be regarded as a proliferation concern. The FCO lists 10 countries of concern including Cuba, India, Egypt, Iran, Iraq, Libya, Israel, North Korea, Pakistan and Syria and 21 academic disciplines of concern including chemistry, biology, physics (including nuclear), mathematics, computing science and mechanical chemical and control engineering. According to information released under the Freedom of Information Act (2005) the numbers of referrals has grown from 4 in 1998 to a peak of 740 in 2002.

In the USA a similar system, concerning entry procedures for all foreign visitors including students, was established in 1996 by the Illegal Immigration Reform and Immigrant Responsibility Act, extended by the Patriot Act, in 2001, and the Enhanced Border Security and Visa Entry Reform Act, of 2002. Section 416 of the Patriot Act required the Attorney General, by 1st January, 2003, to implement fully the foreign student visa-monitoring program established by the Illegal Immigration Reform and Immigrant Responsibility Act (1996) and expand the program to include other approved educational institutions such as flight schools, language training schools, and vocational schools. Section 501 of the Enhanced Border Security and Visa Entry Reform Act, 2002 establishes a Foreign Student Monitoring Program which empowers officials to maintain up-to-date information on foreign students and exchange visitors in the US.

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27 See for example ‘Mr Boswell for the Secretary of State for Education to Mr Willetts’ Hansard (Commons), written answers, vol 247, 19th July 1994, col 137-138.
According to the American Association for the Advancement of Science scientific and engineering research and training are particularly affected because applicants are more likely to study one of the sensitive subjects on the government's Technology Alert List. As a result, they incur greater security checks by the Visas Mantis Program, - a security review procedure involving multiple US government agencies, designed to identify visa applicants who may pose a threat to national security by illegally transferring sensitive technology.29

Surveys conducted since 2001 have indicated that such visa controls are generating a decline in the number of foreign students enrolling in US colleges and universities (Arnone, 2004; Council of Graduate Schools, 2004).30 On 13th December 2002 the Presidents of the US National Academies of Science issued a statement highlighting the damage that visa restrictions on foreign scientists were doing to US science and sought changes in the implementation of legislation.31 In 2005, forty leading scientific societies and higher education associations released a statement expressing their concern about restrictions on the movement of foreign scientists and engineers within the USA and called for further modifications because the US “risk[s] irreparable damage to our competitive advantage in attracting international students, scholars, scientists, and engineers, and ultimately to our nation’s global leadership”. The statement, Recommendations for Enhancing the U.S. Visa System to Advance America’s Scientific and Economic Competitiveness and National Security Interests, was signed by all three presidents of the National Academies. 32

**Governance Measures Covering Scientific Information and Experiments**

Recent increased concerns about bio-security have also led to attempts to govern the transfer of information and modify scientists’ traditional freedom to disseminate results. In the United States the existing balance between national security and freedom to publish was established in National Security Decision Directive 189, issued by former President Ronald Reagan in 1985 and reaffirmed by National Security Advisor Condoleezza Rice in November 2001.33 This directive guaranteed that there would be “no restrictions…upon the conduct or reporting of federally-funded fundamental research that has not received national security classification” (USA, 1985). Shortly after its reaffirmation in 2001 the term

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30 However, figures released for 2005 from a survey carried out by the Institute of International Education show an increase in new enrolments of international students from a year ago at 34% of responding institutions - although 33% reported a decline. Among the responding institutions with more than 1,000 international students, 43% reported a decline in total international student enrolments for Fall 2005, while 33% reported an increase. See [http://opendoors.iienetwork.org/?p=69734](http://opendoors.iienetwork.org/?p=69734)


32 Available at [http://www7.nationalacademies.org/visas/May%202018%20Joint%20Statement.pdf](http://www7.nationalacademies.org/visas/May%202018%20Joint%20Statement.pdf)

33 Available at [www.fas.org/irp/offdocs/nsdd/nsdd-189.htm](http://www.fas.org/irp/offdocs/nsdd/nsdd-189.htm)
‘sensitive but unclassified’ became vogue as a means of preserving confidentiality without formal classification. In January 2002, as part of the effort to safeguard ‘sensitive but unclassified’ information, more than 6,500 declassified documents relating to sensitive chemical and biological warfare information began to be withdrawn from public access.\(^{34}\)

Self-governance measures to control the dissemination of information have been introduced by the US scientific community as a result of increased concerns about the potential misuse of information.\(^{35}\) Following a 2002 White House proposal that journal editors should not publish “sections of articles that give experimental details researchers from other labs would need to replicate the claimed results” to create biological weapons (Broad, 2002), the American Society for Microbiology (ASM) which publishes *Infection and Immunity, Journal of Bacteriology* and *Journal of Virology*, adopted publication guidelines. These guidelines require ASM reviewers to inform editors of any manuscripts containing information or methods which “might be misused or might pose a threat to public health [sic] safety” (Atlas, 2002).\(^{36}\) The impact of these additional prepublication controls has been relatively light: of the 13,929 manuscripts submitted to ASM journals in 2002, 313 manuscripts covering ‘select agents’ received special screening and two of these received additional screening by the full ASM publication board (NRC 2004:83).

However, the controversy surrounding whether all scientific information ought to be freely disseminated reached a peak with the publication of the three papers (listed in the introduction) and the resulting calls for changes to publication procedures that promote the free and widespread diffusion of scientific information (Atlas, 2003; Wallerstein, 2002; Cozzavelli, 2003; Malakoff, 2003; Purver, 2002). In February 2003, 34 journal editors, including the editors of *Science, Cell* and *Nature*, responded by issuing preliminary suggestions for a self-governing framework to be applied during the peer review process (Journal Editors and Authors Group 18th February 2003). In a commentary published in *Nature* explaining this move, the editors stated:

> Scientists and their journals should consider the appropriate level and design of processes to accomplish effective review of papers that raise such security issues… We recognise that on occasion an editor may conclude that the potential harm of publication outweighs the potential societal benefits. Under such circumstances the paper should be modified or not published.\(^{37}\)

This statement of intention was quickly followed by the convening of an expert panel by the National Research Council of the US National Academies under the chairmanship of Professor Gerald Fink. While

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\(^{35}\) These controls are not without precedent. In the early 1940s the joint National Academy of Sciences-National Research Council “Advisory Committee on Scientific Publications” headed by Luther P. Eisenhart explored options for restricting publication of information about nuclear research and secured the co-operation of 237 scientific journals (Cochrane, 1978, pp. 386-387).


\(^{37}\) They justified their action by stating: ‘We recognise that the prospect of bioterrorism has raised legitimate concerns about the potential abuse of published information… we are committed to dealing responsibly and effectively with safety and security issues that may be raised by papers submitted for publication, and to increasing our capacity to identify such issues as they arise’ (Nature, 2003).
the resulting report - *Biotechnology research in an age of terrorism: confronting the dual use dilemma* (2004) - recognized that scientists have non-peer review publication methods available for sharing research results. The report also recommended a pre-publication review of the content of scientific manuscripts for security sensitive information. The Committee recommended that the journals apply particular scrutiny to publications that:

1. Would demonstrate how to render a vaccine ineffective;
2. Would confer resistance to therapeutically useful antibiotics or antiviral agents;
3. Would enhance the virulence of a pathogen or render a non pathogen virulent;
4. Would increase transmissibility of a pathogen;
5. Would alter the host range of a pathogen;
6. Would enable the evasion of diagnostic detection modalities; or
7. Would enable the weaponization of a biological agent or toxin. (NRC, 2004)

Following on from the Fink Report, and reflecting the larger body of work that the US National Academies has undertaken on science and security the *Committee on Advances in Technology and the Prevention of their Application to Next General Biowarfare Threats*, an ad hoc committee of the National Research Council and the Institute of Medicine, was convened to examine current trends and future objectives of research in the life sciences as well as technologies convergent with the life sciences enterprise from other disciplines (e.g. nanotechnology), that may enable the development of new generation of biological threats over the next five to ten years. (IoM and NRC 2006)

Differing from the Fink Committee in that it adopted a more global perspective, and addressed the increasing pace of advances in the life sciences as well as related and convergent technologies which are likely to alter the biological threat spectrum, the committee envisioned a ‘broad-based intertwined network of steps…for reducing the likelihood that [relevant] technologies…will be used successfully for malevolent purposes (ibid p4). Like the Fink Committee, this Committee made broad recommendations in their report which they believed that when taken in aggregate ‘will likely decrease the risk of inappropriate application or unintended misuse (ibid). These included the endorsement and reaffirmation of policies and practices that to ‘the maximum extent possible, promote the free and open exchange of information in the life sciences’; the recommendation to adopt a broader perspective on the ‘threat spectrum’ so that recognition could be given to the inherent limitations in any agent-specific threat list; recommendation to strengthen and enhance scientific and technical expertise within and across the security communities; the recommendation to adopt and promote a common culture of awareness and a shared sense of responsibility within the global community of life scientists, and finally the committee recommended that the public health infrastructure and existing response and recovery capabilities be strengthened (ibid p 5).

As this section has shown the regime against the hostile use of disease is broad and covers a wide, and increasing, range of activities. The effectiveness of the controls depends to varying extents on other

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38 For example, presentations at scientific meetings, Internet postings, email exchanges.
nations adopting similar forms of governance. As a consequence, many of these controls are being globalised, and several nations are adopting new bio-security measures that change the traditional governance of science. Given that these measures are expanding in scope and geographical coverage the next section explores the implicit framing assumptions that underpin them.

Section 3. Designing Effective Policy: The Importance of Framing Assumptions

Recent changes in the governance of science and technology are therefore part of a wider historical evolution driven by such events as the discovery of the scale of the USSR biological weapons program; similar findings about the Iraqi program and how much it drew on dual use facilities; the failed attempt to strengthen the BWC in 2001; the rapid advances in biological sciences and their close historical connection to biological weapons production; the particularly rapid rate of change in scientific areas such as vaccinology, immunology and the study of pathogenesis and zoonosis; the diffusion of capabilities through dual use technologies; and an increased perception of threat. As a result, the governance measures that address research are likely to continue. While the USA is leading the introduction of these new governance measures, the extent of international collaboration with the US science system, together with the gradual adoption and diffusion of governance measures through organisations like the EU, suggests that these measures will be found in other states and science systems in the foreseeable future (McLeish, 2004, McLeish and Nightingale, 2005). Given that initial reports suggest that these controls are already having an impact on the US science system (Atlas, 2002, 2003; Gaudioso and Salerno, 2004), there is a legitimate science policy need to evaluate the policies and explore how they might be improved.

Governance measures thus far introduced to address the proliferation of technological capabilities related to biological weapons have drawn heavily on previous measures used for nuclear and chemical weapons. Modelling policies in one area on successful policies in another related policy area is a standard part of technology governance (Braithwaite, 1994; Braithwaite and Drahos, 2000), but is dependent for its success on the appropriateness of the extrapolation. This makes the successful development of policy under conditions of uncertainty dependent on the implicit framing assumptions (Acha, 2002) of policy makers because interconnected, and often unarticulated, assumptions about the world structure policy makers’ understanding and guide their practical actions (Searle, 2001).

In this policy area one needs to ask whether appropriate extrapolation and selection of policy models is occurring. Is account taken for the underlying technologies being biological rather than nuclear or chemical? Does the duality of the technology with its legitimate applications rather than just its prohibited military applications, and the degree of duality, make an impact in the selection of models. Is account being given to the differing understandings of technology underpinning the previously successful policy measures? And finally, is the extrapolation from one policy environment to the other drawing on salient features of the original policy?
The biological nature of biological weapons and their underlying technologies suggests that care must be taken for a number of reasons when extrapolating governance measures from the nuclear or chemical weapons environment to the biological weapons environment. For example, the amount of material needed to inflict a fatal dose might be orders of magnitude smaller for biological weapons than for chemical ones, which makes the detection of production facilities, particularly at a distance, more difficult. Furthermore, pathogens can be grown with readily available feed stocks, which makes the materials-balance verification methods used for organo-phosphates and enriched uranium problematic to apply in this context. Additionally, being living things, pathogens can be grown rapidly suggesting it might be possible to scale up production in a shorter period of time compared to the time needed for nuclear and (to a lesser extent) chemical weapons production. And finally, the underlying science and technologies behind biology are rapidly advancing and diffusing globally, so that the capabilities required to potentially develop advanced weapons are diffusing to more nation states and are said to be becoming easier and cheaper to acquire.

Secondly, the policy issue would not be so complex if the underlying technologies only had a single military application. For such single use technologies, it is often possible to hinder access to the weapons by controlling access to artefact, even if, as was the case with the Soviet nuclear programme, it is possible to eventually innovate around controls. With dual use technologies, however, governance is more difficult because states have legitimate reasons for acquiring and developing these technologies. Moreover, controls on dual use technologies can generate substantial social costs. Their diffusion in organisations outside the direct control of States, such as universities and multinational firms, increases the number of actors of security concern (including scientists engaged in legitimate research) making policy making more difficult as these organisations have legitimate concerns about the impact of controls on their socially beneficial activities. Moreover, with dual use technologies states can develop their own indigenous biotechnology capabilities far more easily than with nuclear technologies, suggesting that the effectiveness of measures like export controls, which rely on imbalances between states’ technological capability, might become limited in the future as more states develop indigenous technological capabilities.

Thirdly, definitions, models and understandings of technology change over time and are often specific to particular classes of technologies. Over the Cold War period, for example, during which many of governance measures for nuclear technologies were developed, understanding of technology changed substantially: the early period was marked by a focus on physical artefacts, then technology was understood in terms of bodies of knowledge reflecting the _techne_ and _-ology_ of technology (see for example, Pavitt, 1999; Rosenberg, 1982; Freeman, 1982). Today, technology is understood in terms of both physical artefacts (both tangible and intangible) and socially distributed bodies of knowledge, both of which only generate functions through interactions with a wider technological infrastructure or regime (Nightingale, 2004). Similar changes have occurred in policy-makers’ understanding of the relationship between science and technology. In the initial post World War II period the focus was on linear models
(both science push and market pull), then understanding moved towards ‘coupling models’ that linked research with market demands (i.e., Rothwell, 1977; Kline and Rosenberg, 1986) and then in the post-Cold-War period there has been a much larger focus on systems models that take into account wider institutional and organisational structures that promote the accumulation and diffusion of technological capabilities (see, Martin and Nightingale, 2000). Within these later models, science is far less likely to take centre stage and there is much more appreciation of the sectoral differences in patterns of innovation (Pavitt, 1984; Archibugi, 2001) the indirect relationships between science and technology (Rosenberg, 1982) and the role of tacit knowledge, person embodied problem solving skills, instruments and access to networks as the main routes through which scientific research is disseminated (Gibbons and Johnston, 1974; Hicks, 1995).

Lastly, when extrapolating from one successful regime to another, it is not always clear what should be extrapolated and what was the cause of its successful implementation in that policy environment. For example, the success of the nuclear regime could be the focus on the clear goal to prevent the diversion of fissile material from civilian use to military applications, in which case a focus on technology transfer is appropriate. Or, it could be that the Three Mile Island accident created a ‘community of shared fate’ within the nuclear industry, which was reinforced by the international insurance industry, to drive security and safety standards upwards through a process of ‘continuous improvement’ rather than defining and enforcing minimum regulatory requirements (Braithwaite and Drahos, 2000). Or, it could be that success was achieved because a flexible approach that could adapt easily to new circumstances in an unpredictable world was put in place. Or, it could be that the regime has developed an almost perfect ‘enforcement pyramid’ (Braithwaite, 1993; 2002) with a clearly defined path of increasingly coercive measures, from informal co-operative discussion directly up to the UN Security Council. As this example shows, directly extrapolating from one regime to another depends on framing assumptions and can often be neither direct nor extrapolation.

These factors can all be seen in the history of governance measures for nuclear technologies. When export controls were first introduced they focused on the flow of tangible technologies and have gradually expanded to cover the legitimate accumulation of stocks of intangible technology, reflecting both improved understanding of the nature of technological capability accumulation and the problem of dual use. The remainder of this paper suggests that this contingency means that there will be a range of different ways of understanding the dual use problem and that that understanding will influence the types of policies that are proposed and their effectiveness.

The way in which framing assumptions influence policy can be extrapolated to biological technologies. If one were to take an extreme science-push model of technical change, focus only on prohibited uses and extrapolate directly from measures that worked for nuclear technologies, then the policy solutions that might be proposed to govern biological weapons would be likely to focus on measures that restricted the diffusion of dangerous scientific information, pathogens and materials. Linear models of innovation imply that science can be directly applied to produce technology, and since the technologies are dangerous so is
the science. However, such models are likely to under-estimate the costs of development compared to research, overlook the large number of other knowledge sources that have to be integrated to develop technology, and focus inappropriately on high-tech research (cf., Rosenberg, 1982; Pavitt, 1999). Moreover, by seeing artefacts as intrinsically dangerous, it has the potential to lead policy makers to overlook the enormous technical difficulties involved in moving from a dangerous pathogen to technical systems which enable a pathogen to be used as a weapon with the potential to infect and possibly kill more than a few people, and the even larger technical problems associated with developing a biological weapons for mass destruction purposes.\(^{39}\) Similarly, by solely focusing on hostile applications, it overlooks the socially beneficial outputs of research. As a result, such a model is likely to over-estimate the benefits of controls, under-estimate their costs, overlook alternatives and lead to ineffective policy.

While some of the knee-jerk reactions to the publications of the papers listed in the introduction came close to this model, within the main policy discourse the traditional way of modelling the dual use problem remains in terms of technology transfer. The next section critically evaluates this model and compares it to an alternative model in which dual use is understood in terms of technological convergence. These differences suggest that while it is useful to extrapolate from successful experiences in other policy environments, it may not necessarily be the best solution.

### Models for Understanding Dual Use

The differences between the two models of dual use considered here can be understood in terms of differences in how they frame the relationship between an artefact and a technological function (see Nightingale, 2004).\(^{40}\) The traditional way of understanding technology regards technological functions as intrinsic, and innovation as primarily about an inventive \textit{event} followed by the relatively costless diffusion of technology.\(^{41}\) Consequently, the traditional way of framing dual use sees technologies as having

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\(^{39}\) WMD require large scale, state based programmes that generate technological capabilities that are beyond the capabilities of terrorist organisations (Leitenberg, 2005). Moreover, the cell-like organisational structure of terrorist groups is precisely the opposite of the information rich organisational structures most suitable for innovation (Jackson, 2000).

\(^{40}\) In Nightingale (2004) science and technology are distinguished in terms of what Searle (1995) calls ‘the direction of fit’ that relates to whether ideas are changed to fit the world, or the world is changed to fit ideas. Scientific ideas (theories, explanations etc) are meant to be true and are changed until they match how the world is, while technologies are meant to generate desired functions, and the process of innovation involves changing the world fits a (desired) idea of how it should function (Searle, 1995). The intentional level of ideas, desired behaviours and functions is therefore conceptually distinct from the intrinsic physics of the world. The technologies’ functions are not solely determined by their intrinsic properties and innovation is not an event where an artefact/function is developed. Instead, technologies’ functions are dependent on interactions between the intrinsic properties of a technology, its relationships with the wider environment, which typically includes other socio-technical systems and people’s understanding. Innovation is a process of changing the intrinsic features of the world until they match the desired functional behaviour (Nightingale, 2004).

\(^{41}\) The substantial empirical difficulties involved in technology transfer where then typically explained away in terms of the difficulties of transferring tacit knowledge, which acted like physicists ‘dark matter’ as a poorly theorised substance that could explain a whole range of empirical problems (see, Nightingale, 2003 on tacit knowledge, and Nightingale, 2004 for an argument that tacit knowledge remains important but is a distraction from the real theoretical issues).
intrinsic fixed functions, and accordingly regards dual use technologies as technologies that have functions which can be applied in both civilian and (prohibited) military settings. Since the technological function in biological weapons is dangerous then the dual use science or technology that is transferred is also considered intrinsically dangerous. The policy problem is therefore understood in terms of technology transfer and the prevention of dangerous research and technology getting into hostile hands.

An alternative framing of dual use, presented for the first time in this paper, can be generated by modernising our understanding of technology and regarding technological functions as imposed properties rather than intrinsic ones. The same compact disc, for example, can have multiple functions and can be used to store data or music, as well as stopping a hot coffee cup marking a table (Nightingale, 1998) showing that functions aren’t intrinsic (McLeish, 2004; 2002). In this model, not only does the intrinsic physics of a technology in relation to its wider environment determine the extent to which it can perform certain functions over others, but interestingly it is the imposed function rather than the intrinsic physics that defines what a technology is. This is why a safety valve, is still a safety valve with the function of stopping explosions, even when it malfunctions (i.e., its intrinsic physics fails to perform the imposed function it was designed to perform) (Searle, 1995:19).

In this second model technology is defined as all the knowledge, concepts, experimental processes, tangible and intangible artefacts and wider socio-technical systems that are required to recognise technical problems and to conceptualise, formulate, research, develop, test, apply, diffuse and maintain effective solutions to those problems. Within this conception of technology it is incorrect to think of technical change in terms of an inventive event and then an unproblematic diffusion process. Instead, innovation is a difficult and costly process, sometimes beginning with an invention, (but more often a problem with existing technology), by which the intrinsic physical properties of technologies and the environment are changed to match a desired intentional function. This conception of technology allows one to frame dual use policy in terms of technological convergence (Rosenberg, 1963). Technology convergence occurs when different final products (bicycles and sewing machines, or prohibited weapons and vaccines) share some of the same technologies and knowledge within their production processes (such as machine tools with bicycles and sewing machines and modern biotechnology with vaccines and prohibited biological weapons) i.e. different downstream technologies share some of their upstream technological inputs.  

The remainder of this section explores the strengths and weaknesses of these two models of the dual use problem.

**Dual Use as a Technology Transfer Problem:** Framing dual use policy in terms of preventing the transfer of ‘dangerous’ research and technology to states or non-state actors who potentially might use it

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42 Within this socio-cognitive frame the dangerousness of research is context dependent and related to an artefacts relationship to wider socio-technical systems that are both costly and difficult to set up. Thus, even pathogens like anthrax bacteria have historically been safely used in well-maintained containment conditions, even though they are extremely dangerous when inhaled.
for hostile purposes is the main way in which the issue of dual use is presented in current debates. This draws heavily on governance models for nuclear and chemical weapons whereby the prevention and oversight of technology transfers has played an important role.

However, this way of framing the problem assumes that technological functions are fixed and consequently focuses attention on the invention and diffusion stages, thereby under-estimating the difficulties involved in moving from an invention to a working technology, and the similar substantial costs involved in transferring technology (Nightingale, 2004). Although considering technology or research as being inherently dangerous allows it, in theory, to be assigned a definite risk category that can be entered into some form of cost-benefit type calculation to guide policy, it is not at all clear in practice how one defines ‘dangerous’ and how one draws boundaries around what is, and what is not, to be considered dangerous. For example, it is hard to see how to assess the relative costs or benefits of a) putting the 1918 flu virus genome on the web, b) highlighting the pathogenicity genes in the *Yersina pestis* genome, or c) developing immune evasion technologies for gene therapy. Since the benefits of such pieces of research are also extremely difficult to quantify, a policy of weighing up costs and benefits is of limited practical use when there is no agreed way of defining or comparing either.

The problem encountered here is not simply that definitions are not agreed in practice but that unambiguous definitions cannot be agreed in principle - ‘dangerous’ is not a descriptive term that denotes a property of something, but is an expressive term that refers to how we think about the possible implications of the properties of something (Hopkins and Nightingale, forthcoming). Similar problems occur in labeling a technology ‘risky’ or ‘beneficial’. While the intrinsic physical properties of a technology interact with its environment to generate the function that we regard as dangerous or risky, ‘dangerousness’ or ‘riskiness’ can never be fully defined in terms of those physical properties alone. Being context dependent, different people will rank the subjective terms in different ways, which complicates the policy process and has caused questions to be asked about the assignment of risk categories (Tuerlings and McLeish 2004). Furthermore, even if one could define dangerous in practice obvious questions remain about the objectivity of expert opinion in risk assessments of bioterrorism.

Despite these theoretical concerns, within the current policy discourse the dual use dilemma is mainly tackled by attempting to find fixed definitions and categorising lists of pathogens or experiments according to those fixed definitions. While this appears eminently sensible, the difficulty of defining dangerousness does not go away: in interviews conducted by the authors several leading virologists in the UK expressed their concern that some pathogens they regarded as being particularly ‘dangerous’ were not found on the UK control lists developed by government, whilst others they considered as not being dangerous were labelled dangerous and subject to additional controls (McLeish and Nightingale 2005).

Possibly the most important problem with policies directed towards controlling dangerous things is that if ‘dangerous’ is context dependent, then almost anything could be potentially dangerous. The scientific disciplines related to biological weapons development, particularly genetic engineering and immunology, are considered immature technologies that are advancing rapidly and proliferating through legitimate
channels to different settings. Approaches such as the fixed-definition or agent-specific/experiment-specific threat list approaches, while no doubt useful will require constant updating. If one considers the potential advances that could be made in immunology and virology over the next few decades to improve understanding of how pathogens shift host then it is hard to see how any research might not be regarded as potentially dangerous. In such a situation there is little inherent limit on the extent of controls, which combined with the inherent weaknesses of controls on things (that can be innovated around) and strong political pressure (for example, related to a public fear of bio-terrorism) could result in policies that generate the worst of all possible worlds: draconian controls that damage legitimate research, have no significant effect on security and reduce the transparency needed to maintain an international regime based on trust. Such controls might impose further substantial social costs if they make the identification and treatment of natural outbreaks or deliberate releases more difficult.

**Dual Use as a Technological Convergence Problem:** A second framing draws on more recent understanding of the contingent relationship between technological artefacts and their functions (Searle, 1995) and their dependence on wider socio-technical systems and practical knowledge. This way of framing the problem sees the governance of dual use technologies in terms of ‘technological convergence’ (Rosenberg, 1963:423) whereby common upstream processes and technologies can be applied to a range of downstream outputs. Dual use is a particular sub-set of technological convergence whereby the same upstream technologies can have both hostile and peaceful downstream applications (Alic et al., 1992; Reppy, 1999). Dual use, as the term is used in this paper, is a further subset that relates to technological convergence between legitimate, socially beneficial applications, such as vaccine development and prohibited uses such as biological weapons.

Because, in this way of framing technology, physical properties and functions do not necessarily match, technical change is not an *event* where a thing-function is generated and can be easily diffused, but a *process* whereby the world is changed until the intrinsic physics of a technology generates a desired effect/purpose/function. For complex technologies this process requires a diverse and complex set of...

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43 Rosenberg originally used technological convergence to explain American industrialisation which he argued had not only involved growing specialisation, complexity and differentiation, but also the ‘introduction of a relatively small number of broadly similar productive processes to a large number of industries. … [specifically] the growing adoption of metal-using technology employing decentralised sources of power’ (Rosenberg, 1963:422).

44 This overlap between technological convergence and dual use is not novel. Ames and Rosenberg (1968) highlighted the how the establishment of the Enfield Arsenal in 1854 marked the beginning of the movement of mass production techniques from the USA to Europe. Indeed, Ames and Rosenberg note that ‘Technical changes in gun making in the nineteenth century were a major source of new machine techniques; and industrialisation in the nineteenth century is overwhelmingly the history of the spread of machine making and machine using’ (1968:827).

45 This implies a distinction is made between innovation and invention. The collapse of these two notions in other framings, focuses attention on innovation as the generation of a new idea (an event), which inappropriately focuses policy attention on cutting edge science. Regime violators are not necessarily interested in the most up to date technology, they are more interested in technologies that work, and are therefore likely to be well established. The value for regime violators of cutting edge research is therefore likely to be more associated with equipment, experimental protocols and people trained to solve complex technical problems, than it is with cutting edge research findings.
knowledge bases to be integrated (Pavitt, 1999). The complexity of this process of knowledge integration means that theory is a poor guide to practice (ibid; Nightingale, 2004) and a large amount of costly trial and error experimentation, knowledge generation and infrastructure is needed to get technologies to function correctly. In some instances the technical problems have been beyond the ability of large state based programs. For example, both the UK and US conducted open-air field tests on animals using aerosolise plague in the 1950s and the tests failed (Leitenberg, 2005: 49).

The complexity of these processes, and the corresponding technological capabilities that are required, suggest a different approach to risks assessments than one that regards pathogens or research as inherently dangerous. Moreover, the differences between the processes that turn the same upstream technologies into different downstream technologies provide a number of opportunities for controls to hinder prohibited technical change and generate a more secure environment, at a lower cost, than controls on the transfer of ‘dangerous’ research.

The potential web of controls is large because technology is not only comprised of tangible and intangible artefacts but also the wide range of other things and activities in the definition: formulating problems, conceptualising solutions and changing the world to reliably make it generate a desired function is a non-trivial activity that typically requires the co-ordination of a specialised division of labour over an extended period, making innovation an organisational and managerial problem as much as a technical one. Within this conception of technology, while science is useful and can in some instances be applied to reduce the costs and time scales involved in experimentation, it is not necessarily the most important, let alone the only, form of knowledge that is necessary. It is after all possible to know how to produce effects without knowing how those effects are produced, and diseases were applied in hostile situations long before their exact modes of action were understood. The complexity of the process that links upstream technologies to a range of downstream applications suggests technologies are not necessarily dangerous in isolation from the wider socio-technical systems and personal intentions that might make them so. Even the most dangerous pathogens, for example, are routinely experimented on quite safely within well-maintained and managed containment laboratories.\textsuperscript{46}

Framing dual use in terms of technological convergence suggests policy should be directed towards hindering innovation processes rather than controlling artefacts. This has the advantage of preventing policies being overtaken by changes in technology, and preventing regime violators legitimately innovating around controls on things. However, this flexibility comes at a cost, as governance measures that cover (imposed) purposes do not provide clear guidance at the level of the artefact about what specifically is and what is not to be the subject of governance. The main problem is that the purposes that are being subject to governance are imposed rather than intrinsic properties. As a result, they will always have the potential to “slip through your fingers” because (a) governance measures are operationalised

\textsuperscript{46} In interview one UK scientist discussed working with open Petri dishes containing live smallpox virus cultures in the 1960s. Scientists worked on the open bench without safety glasses, gloves or containment boxes. Researchers kept their lunch (typically sandwiches) uncovered on the bench next to the live samples and smoked while working, leaving their lit cigarettes on the side of the bench when they needed two hands to manipulate samples.
around artefacts and their intrinsic properties, and (b) artefacts and their functions (or purposes) do not necessarily always coincide. Governance measures that address purposes but are operationalised around artefacts are problematic when new technologies are developed and when old technologies can be applied to new purposes. This slipperiness is one reason why artefact based governance has the potential to be both Draconian and ineffective and why operationalizing the control of purposes will be non-trivial.

The governance of purposes rather than things implies that a lighter touch is required in policy design so that the focus is on exploiting the “strength of weak ties” to create webs of governance measures that put barriers in the technology development process (Pearson, 1993). This requires flexible informed judgements to respond to changes in technology, signifying the importance of engaging the informed judgement of scientists. While it is prudent to control access to pathogens, draconian controls will not stop determined proliferators from attempting to source pathogens in nature. The difficulties in turning pathogens into weapons, let alone into, are high that their ‘dangerousness’ to the public, rather than to laboratory staff is potentially limited. A default position on controls would probably be that legitimate scientific research should be unhindered, unless there is a good reason for it to be hindered, given that scientific knowledge is only one of a wide range of knowledge bases required for innovation.

This default position, where policy focuses on purposes rather than things, requires a higher degree of self-regulation within the scientific community, which in turn requires both education and awareness raising. Framing dual use in terms of technology transfer, and consequently framing the scientific community as naively transmitting dangerous knowledge and materials, is unlikely to enculture scientists to cooperate with self-governance. On the other hand, framing dual use in terms of technology convergence allows scientists to perceive themselves as being actors engaged in socially beneficial activities which could be misused and offers them an active identity as ‘guardians of science’ in the fight against BW and bioterrorism, rather than the passive recipients of bureaucratic regulations. In previous research conducted by the authors (McLeish and Nightingale 2005) we found that scientists in the UK were far more willing to become actively engaged with biosecurity governance, and were willing to devote considerable amounts of time to it, if they were seen as ‘guardians’ rather than ‘naïve dupes’ and if they recognised the controls as rational and effective. Framing dual use controls in terms of technology transfer invoked a linear model of innovation that they recognised to be false, and therefore undermined their willingness to actively engage with new security measures. Such a focus would attend to a range of measures that would generate a web of controls. Empirical questions remain about what is the most effective set of measures, and what the costs and benefits of such measures might be, and more importantly how they might change in the light of changes in context, time, place and technology.

**Conclusion**

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47 The focus of policy is not necessarily to control things as an end in itself, but rather as a means to control purposes.

48 We are grateful to Dr Tony Phillips, visiting fellow with the Harvard Sussex Program, for the term ‘guardians of science’.
This paper has highlighted how concerns about bio-security are changing the governance of technology including scientific research. While it is important not to over-state the extent of these changes, they do represent an important new development in science and suggests an increasing intersection between science and security policy. Section 2 contextualised these controls within a historical account of the anti-BW regime that it is neither divorced from, nor determined by changes in the wider world. It highlighted how national and international security legislation has covered scientific research since the banning of BW in the 1970s and the resulting shift towards technology governance. It also highlighted a series of governance changes following the failure of the 2001 attempts to strengthen the BWC and increased concern about the implications of advances in biological sciences.

Section 3 examined the different ways in which biosecurity controls could be framed, and highlights the implausibility of the popular notion that changes in governance were a simple response to an increased threat from bioterrorism. The section highlighted potential problems with policies that frame dual use policies in terms of technology transfer of inherently dangerous materials or knowledge. The section showed the potential difficulties of defining dangerousness, as it is an expressive rather than descriptive term, and the consequent limitations of cost-benefit calculations. Moreover, it also showed how governance measures framed around technology transfer have the potential to be both draconian and ineffective.

An alternative framing of dual use where it is understood in terms of Rosenbergian technological convergence was then introduced which focused on disrupting innovation processes rather than controlling artefacts. Within this policy model the scientific community would take on an active role as ‘guardians of science’ to help prevent proliferation. This model also highlighted that the process of creating technologies that behave in predictable ways is complex, and becomes substantially more complex as one moves from dangerous pathogens, to weaponised pathogens capable of infecting several people, to WMD capable of infecting thousands. While terrorists may be able to generate mass disruption by inducing public fear (Sunstein, 2003), their limited technological capabilities, historical technological conservatism and inappropriate organisational structures suggest they are unlikely to develop WMD capabilities without the assistance of state based programs. Just as linear models of innovation underestimate the difficulty and costs of innovation in science policy, they also over-estimate the risks of innovation in security policy.

This framing of biosecurity policy also raises an important implication about the risks and benefits associated with biodefence research that may be usefully addressed by future research. Biodefence research has a dual use potential, in that it is often necessary to understand how to develop biological weapons if one is to defend against them. While this is allowable under international law, it unfortunately creates exactly the technological capabilities that policy is attempting to prevent. While these capabilities are intended to be applied to peaceful defence, their dual use nature suggests that they represent a considerable risk. Moreover, given the shift away from security through transparency (Walker 2003) that the development of biodefence research programs implies they are likely to undermine the international
trust that has been a key factor in the success of the BWC. Given the very substantial sums of money invested in biodefence, there is a need to critically examine the implicit policy assumption that it increases security and reduces risk exposure.

In conclusion, this paper suggests that Meselson (2000) was correct in highlighting that biological weapons presents a major policy problem for science, and that new governance mechanisms will be needed to prevent what he describes as a 'species threatening’ problem. However, while Meselson highlights the potential dangers of advances in technology and biological sciences, he is not a technological determinist, and he explicitly highlights the possible hostile application of advances in biological science presents a fork in the road rather than a conclusion. Given that advances in biology are likely to continue, science policy is going to have to continue to address security issues, and further research will be necessary to ensure that the dual use dilemma is properly addressed and security restrictions are balanced against their social costs on legitimate activities.

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