Research involving work with potential for military applications (so called "dual-use technologies")

Background information about **dual-use issues in engineering sciences** can be found at the end of the document.

By virtue of the **Swiss Federal Act on the Control of Dual-Use Goods, Specific Military Goods and Strategic Goods** (Goods Control Act, GCA, RS 946.202) and its ordinance (OCB RS 946.202.1), the export of the following goods are subject to the **authorization of the Secretary of State for the economy (SECO)**:

1. dual-use goods, components, software, technology and information
2. nuclear goods, special military goods, strategic goods and other goods subject to national export controls
3. goods that you know or have reason to believe are intended for the development, manufacture, use, passing on or the deployment of nuclear explosive devices, biological or chemical weapons, and their delivery systems (NBC weapons)

save where the OCB provides for an authorization exception. For certain categories of nuclear goods, the export authorization is to be requested to the Swiss Federal Office of Energy (SFOE).

Professors and collaborators at EPFL must comply with these legal and regulatory measures (LCB and OCB). This legislation includes **penal sanctions** in the event of intentional infringement or negligence.

At EPFL, transfer of knowledge, software, demonstrators or prototypes that can fall under the scope of this legislation can occur **in the context of technology transfer, international collaborations or research proposals**, **but also in informal personal contacts.**

So, **before transmission** of information, research results, prototypes etc. to a company, person or entity (even academic) outside of Switzerland, it must be checked whether the data/ information/material/software to be transmitted are **subject to authorization**. To do so, the following annexes to OCB need to be consulted:

- Annex 2 (part 1) – Nuclear Materials, Facilities and Equipment
- Annex 2 (part 2) – Dual-Use Goods
- Annex 3 – Specific Military Goods
- Annex 5 – Weapons and their components – Explosives

EPFL holds a general export license authorizing transfers of dual-use goods (Annex 2, part 2) and goods according to Annexes 3 and 5 to certain countries; the list of these countries appears in Annex 7 to the OCB . Please note: this general license is not valid for certain goods intended for internet or mobile communications surveillance (as defined in the applicable Ordinance, RS 946.202.3), and it does not relieve from the obligation to request an authorization for the export of NBC weapons (see definition above).

OCB and its annexes are available on the SECO web site https://www.seco.admin.ch/seco/fr/home/Aussenwirtschaftspolitik_Wirtschaftliche_Zusammenarbeit/Wirtschaftsbeziehungen/exportkontrollen-und-sanktionen/industrieprodukte--dual-use--und-besondere-militaerische-gueter/rechtliche-grundlagen-und-gueterlisten--anhaenge-.html

In case of doubt, please **contact** the Legal Team at the Research Affairs: Françoise Chardonnens (francoise.chardonnens@epfl.ch).
Applications to SECO are submitted electronically via the Elic platform. EPFL has an Elic account (contact - francoise.chardonnens@epfl.ch or research@epfl.ch)

Some foreign laws on export control, including US laws, differ from Swiss laws in that they **prohibit not only export to certain countries but also access to certain technologies, software and information for persons of certain nationalities**. Professors and researchers at EPFL should therefore be especially cautious in the framework of international collaborations, including with US companies or institutes, and ensure in advance that the foreign legislation on export control is observed.

More detailed information on US and European foreign export control legislation can be found online on the following websites:
US Export Laws: U.S. Department of Commerce (https://www.bis.doc.gov/) and U.S. Department of State (http://www.pmddtc.state.gov/) .
European Export Laws: European Commission (http://ec.europa.eu/trade/import-and-export-rules/export-from-eu/dual-use-controls/).

A brief introduction to “dual-use” in engineering sciences

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This study was commissioned by the EPFL Research Office

This notice is intended to provide you with some useful background information about **dual-use issues in engineering sciences**. Contents include:

1. Concept clarifications and a **definition of dual-use**.
2. A general **ethical framework** to recognize and examine dual-use dilemmas.
3. Some possible **policy options** to address dual-use concerns.

1. Definition of “dual-use”

Dual-use issues in science are increasingly discussed in the literature and in policy-making, as well as in the media and in the public discourse. However, there presently exists no widely accepted definition of dual-use. While previously the term was used in relation to specific technology applications, latterly research too has entered the debate on dual use.

A clear definition is necessary to ensure adequate consideration of the ethical issues involved. This definition should be neither too narrow, hence liable to rule out issues of genuine importance, nor too wide, making oversight of dual-use science ungovernable (Resnik, 2009).

For example, if the definition of dual-use is limited to particular experiments in the life sciences involving dangerous biological or chemical agents, then scientists or policymakers may fail to take into account other types of potentially dangerous research, such as research that could be used to play havoc with computer networks, jeopardize buildings or contaminate the food supply[1]. If the definition of dual-use is too wide in scope, it may be applied to areas of science that are very unlikely to be used for malevolent purposes, place futile administrative burdens on scientists, and eventually impede innovation that might prove beneficial to society.

[1] As remarked by David Resnik (Resnik, 2009), one of the most contentious examples of dual-use research had nothing to do with research with pathogens or chemicals, but a mathematical model of contaminating the U.S. milk supply (Wein and Liu, 2005).

1.a. The concept of dual-use

Before exploring in more detail a workable definition of dual-use, it might be useful to differentiate between two main dual-use concepts (Rath et al., 2014): the **military *versus* civilian purpose** concept of dual-use, and the **benevolent *versus* malevolent purpose** concept of dual-use.

Military *versus* Civilian purpose

Early definitions of dual-use refer to technology that has both military and civilian applications. This interpretation of dual-use gained currency in the debate on weapons and technology exports which began soon after World War II, serving to underpin national export control legislation and international treaties for the US and its allies (te Kulve and Smit, 2003). It is also applied in non-proliferation arrangements concerning conventional weapons and other technologies used in military activities to promote national and civil security (e.g. ballistic and missile technologies, cryptography, etc.). Under the export control regime, access to dual-use materials and technology is restricted to foreign military, while in parallel its own military and civilian environments can derive the benefits of such technologies (Rath et al., 2014).

Since the end of the Cold War, the military/civilian purpose concept of dual-use has been used increasingly to promote economic interests. As such, the dual-use aspect of technology is considered as something that should be encouraged, since it helps to promote advanced defence systems while at the same time pursuing a country's economic competitiveness through integration of the military and civilian contexts and a more efficient allocation of research funds between them (te Kulve and Smit, 2003).

Governance of this approach to dual-use technologies is almost exclusively dependent on national (i.e. export controls) and international (i.e. sanctions) legislation (Rath et al., 2014).

Benevolent *versus* Malevolent purpose

Recent accounts of dual-use in science focus on the distinction between benevolent and malevolent purpose, rather than civilian and military purpose (Rath et al., 2014). The general idea is that dual-use dilemmas arise when a technology has a primary intended purpose or use which is good, and a secondary purpose or use which is bad and is not intended by those who developed the technology in the first place.

This notion of dual-use was first introduced immediately after World War II, in the debate on the application of nuclear physics to the development of weapons of mass destruction. More recently, it was widely employed in discussion of the increasing risk of malevolent use of biotechnology by terrorists and criminals, following the anthrax attacks in the autumn of 2001 and the publication of several research works on highly virulent pathogens. Besides concerns for human health, an increasing concern for human rights-related misuses of technology prompted the diffusion of this wider definition of dual-use, which has the potential to address issues as diverse as individual or social wellbeing, privacy, and environmental, information, or infrastructure security.

Governance of this approach to dual-use does not depend solely on national and international legislation, but also on self-regulation in the engineering profession (e.g. research ethics, codes of conduct, institutional oversight) and on a stronger role for civil society in determining what should count as benevolent/good (Rath et al., 2014).

The categories benevolent/malevolent encompass civilian/military purposes, insofar as some military non-offensive purposes might be good (e.g. the aerosolisation of a pathogen undertaken for protective purposes, in order to understand the nature and dangers of aerosolisation with a view to preparing safeguards against an enemy known to be planning to use the aerosolized pathogen as a weapon).

Moreover, the distinction between benevolent/malevolent purpose seems more suited to addressing dual-use concerns in engineering, since it focuses on the potential for engineering science to be misused, regardless of the context (i.e. civilian or military) in which it is developed.

1.b. Dual-use items

Based on the **benevolent *versus* malevolent purpose** concept of dual-use, we can move forward to outline a definition of dual-use in engineering.

Philosopher John Forge claims that, in order to find a workable definition, we need to distinguish three kinds of dual-use items: **research**, **technology**, and **artefacts** (Forge, 2010)[2].

Research and Technology

The term **research** covers more ground than "experiment". It refers to the first stage in the continuum of research and development (R&D), where emphasis is on the activities of discovery, invention, design, feasibility, prototype building, testing, etc. In other words, research includes all steps in the creation of knowledge of how to do something, while **technology** is that knowledge itself, including the plans, designs, blueprints, etc., that provide directions on how to make something.

Note that the potential to result in technology is inherent in research: even if a project is stopped once research is completed, a new technology could issue from it if someone else were to bring this work to fruition.

Artefacts

The term **artefact** is used here to refer to any concrete manifestation of the application of research and technology. As man-made things, artefacts are objects that can be distinguished from the knowledge of how to make them.

[2] The following discussion about the definition of dual-use draws extensively on Forge's work (Forge, 2010; Forge, 2013).

The distinction between **knowledge and artefacts** is important, since they involve **different approaches with regard to the control of their potential dual-use**:

Oversight and control of dual-use **knowledge** depends mainly on the capacity of **individual scientists/engineers and the scientific community** (e.g. research institutions, professional associations, scientific journals, etc.) to assess and address dual-use concerns. See **part 3** for examples of possible strategies.	Control of the supply of dual-use **artefacts** is almost exclusively dependent on **national** (i.e. export controls) **and international** (i.e. treaties) **regulations**, that is, on **governmental authorities** capable of imposing restrictions and sanctions. Nevertheless, scientists/engineers can provide expert advise to authorities and may play an important role in classifying artefacts as dual-use.

Understanding the **relationships between research and technology** may help to identify dual-use problems that are relevant to engineering.

Consider the following **example on aerosolisation technology**[3]:

> The technology $\mathbf{T^m}$ used to make an aerosol for the control of gypsy moths (i.e. the primary-intended purpose), containing particles of bacteria only a few microns in size, can also be used to produce an aerosol of anthrax, since the bacteria are very similar. Here, the self-same technology $\mathbf{T^m}$ capable of having an effect on different organisms is dual-use, since it may give rise to both "good" (or "neutral") and "bad" outcomes, i.e. it may provide the means to harm by allowing weapon development. Moreover, if a given research on aerosolisation R^a gives rise to a dual-use technology $\mathbf{T^m}$, then evidently $\mathbf{R^a}$ was dual-use research, even if no one had taken this possibility into account. Furthermore, $\mathbf{R^a}$ may be dual-use even if no technology $\mathbf{T^m}$ has yet come on line from it.

While knowledge, like research or technology, can certainly be included in the category of dual-use, the inclusion of **artefacts** – i.e. concrete objects already developed – complicates the issue.

On the one hand, there are highly dangerous artefacts that have a heightened potential for use as components of improvised weapons, such as the nuclear waste elements of a dirty bomb, pathogens (e.g. anthrax, smallpox), poisonous gases (e.g. sarin, tabun), etc. As these artefacts raise important concerns about weaponisation, they need to be carefully stored and supervised to stop them from falling into the hands of those who have no right to their use.

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[3] The example was provided by the British Medical Association in its second influential report on bioweapons (BMA, 2004), later cited and discussed by Forge (Forge, 2010).

On the other hand, there are a number of apparently trivial artefacts that can be used as components for making things quite unrelated to their primary purpose. For example, ammonium nitrate is a common fertilizer but can also be used to make improvised bombs. The same can be said of various mundane objects such as nails, ball bearings, timers, batteries, mobile phones, etc., that were designed for a good (or morally indifferent) purpose and could be used as means to harm, namely to manufacture weapons. Including objects that have a wide range of uses and are readily available could make the definition of dual-use unworkable, since their supply cannot be easily controlled.

And on the top of this, there are artefacts that are neither mundane objects such as nails or timers, nor highly dangerous such as nuclear waste or pathogens, which raise concerns with regard to their possible dual-use. Consider for example solid-state lasers used in industrial applications, or bio-inspired small drones that may be employed in rescue situations: both artefacts could be used for bad purposes or engineered to manufacture weapons. The inclusion of any high-tech artefact that could have some bad use would make the category of dual-use unwieldy and impossible to control.

The only viable solution is to judge on a case-by-case basis whether or not an artefact is dual-use. This could be done through careful consideration of the contextual factors that make the bad use of an artefact more likely (see **1.c.**). Contextual factors should also be taken into account in judgements about the potential for knowledge (such as research or technology) to serve both beneficial and malevolent purposes.

1.c. Contextual factors relevant to dual-use

Contextual factors that may affect the classification of knowledge or artefacts as dual-use are functions of space and time, meaning that the definition of a dual-use item is not etched in stone. In other words, dual-use is not typically inherent in research (R), technology (T), or an artefact (A) itself, but depends on the social context in which the R/T/A is developed. By implication, R/T/A duality is not a constant but may evolve over time, while similarly a potentially dual R/T/A may never display dual uses.

At least three contextual factors need to be taken into account to classify R/T/A as dual-use (Forge, 2010): **threat**, **risk**, and **value**.

Threat and Risk

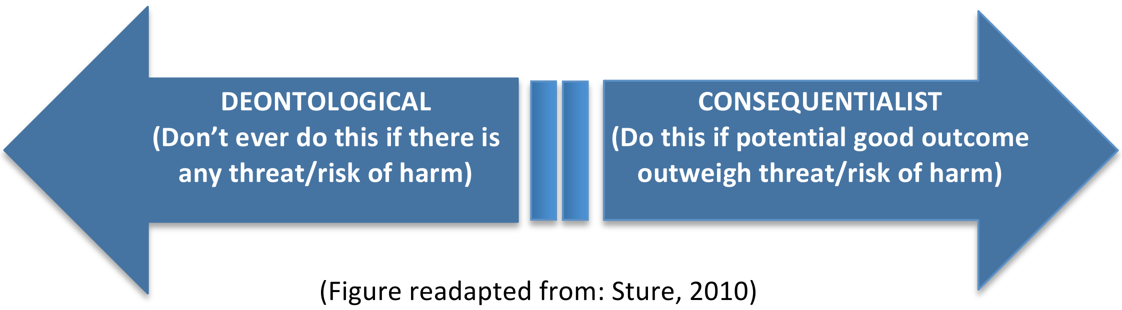
A **threat** is the possibility that R/T/A could be used for bad purposes. Assessment of a dual-use threat includes evaluation of its likelihood, i.e. what is the probability that it will come to pass. There is no simple answer, since threats come and go depending on the social context (for example, a knife is dual-use as we walk through a security scanning system, but ceases to be so once we step outside). However, at least for an already existing object as an artefact, dual-use threat must imply a concrete possibility of malevolent use (e.g. if a group is bent on exploiting the bad use).

Where a certain level of knowledge and technical ability is required to put into effect the potential bad uses of a research or technology, the term **risk** is more apposite. Consider for example the development of bioweapons using research findings in synthetic biology, or the making of newly designed nuclear weapons. At present, the kinds of groups able to carry out such programmes are more limited than those able to make improvised weapons out of ammonium nitrate, for example.

Value

Judgements about threats and risks rely on a set of **values** which in turn may alter the definition of R/T/A as dual-use. Therefore, assessment of dual-use threats and risks requires the value system that informs dual-use categorisation to be made explicit.

Drawing on relevant ethical theories in engineering ethics, it is possible to distinguish at least **two value systems**: **deontological** and **consequentialist**. Very broadly, a deontological-type value system based on the imperative of doing no harm to others will consider any threat/risk as a sufficient reason to ban or restrict access to dual-use R/T/A. On the other hand, a consequentialist-type value system will balance the threat/risk of harm against possible compensating good that may ensue from dual-use R/T/A.



(Figure readapted from: Sture, 2010)

Consider for example research in applied nuclear physics on the enrichment or reprocessing of spent nuclear rods to make new and high-power fuel rods, where findings from research could also be used to make weapons-grade uranium and plutonium. Whether this research should count as dual-use use will depend on the value system used to assess the potential risks and benefits.

Judgements about dual-use have no simple answer, since they need to consider contextual factors that are difficult to estimate and can change over time. Nevertheless, based on the previous discussion, it is possible to attempt a **definition of dual-use** as follows:

> ***A research, technology, or artefact is dual-use if there is a concrete threat or a sufficiently high risk that it can be used to serve malevolent purposes (e.g. design or produce a weapon, endanger human health, compromise security, threaten fundamental human rights, etc.), where in neither case this is the intended or primary purpose.***

2. Ethical framework to assess dual-use dilemmas

So-called **"dual-use dilemmas"** in science arise because the same piece of knowledge (as research or technology) or artefact (as a material outcome of knowledge) that has been created for good ends has the potential to be used to cause harm (Miller and Selgelid, 2008; Miller, 2013).

A dual-use dilemma is an **ethical dilemma** because it involves two morally significant options both of which have valid arguments on their side. Specifically, from the standpoint of the scientist/engineer, the dilemma presents a choice between **intentionally doing good** and foreseeably **providing others with the means to do harm** (Miller, 2013). Note that the dilemma arises not only for the individual scientist/engineer, but also for those who have the power to assist and oversee their work (e.g. universities, research institutions, professional associations, funders, governments).

The dilemma is possibly more apparent in areas of science that function on an engineering or "construction" model – e.g. nanotechnology, robotics, synthetic biology, etc. – than in disciplines that adopt a more descriptive epistemological paradigm – e.g. mathematics, physical theory, astronomy, etc. (Miller, 2013).

A recent **example of a dual-use dilemma** in the life sciences is **research on the virus H5N1**, which causes bird flu:

> **Two teams of scientists**, at Erasmus Medical Centre (The Netherlands) and the University of Wisconsin-Madison (USA), created a highly transmissible strain of this virus (i.e. transmissible between ferrets, the animals that most mimic the human response to flu) with a view to developing vaccines against similar naturally occurring or artificially created strains of H5N1. A **worldwide controversy** lasting eight months, **involving the scientific community and health and security organizations**, followed the announcement of forthcoming publication of the research:
> http://www.sciencemag.org/site/special/h5n1/index.xhtml
> The **ethical dilemma** in this case was that, although the research was undertaken for the good purpose of developing a vaccine (i.e. **intentionally doing good**), publication had the potential to provide malevolent users with knowledge of how to create a deadly virus (i.e. **foreseeably providing others with the means to harm**).

"Fine-grade" ethical analysis of dual-use dilemmas would explore real and possible benefits and burdens of the two horns of the dilemma, and real and possible recipients of these benefits and burdens (Miller and Selgelid, 2008). Such analysis would also point up a selection of possible solutions to the dilemma, each one involving compromises between present and future benefits and burdens/recipients. As put forward in **part 1**, this could only be done on a case-by-case basis, since dual-use dilemmas arise with regard to a specific piece of knowledge or artefact and should be thoroughly assessed in context.

Moreover, ethical assessment of dual-use dilemmas will depend on the value system that informs the definition of knowledge or artefacts as dual-use. For example, in the case of research on highly virulent pathogens, ethical analysis would weigh scientific freedom against the protection of human health as a basic human good, and would consider what forms of security would be ethically justified in this context.

Assessment of dual-use dilemmas in engineering can be based on a **general ethical framework** that includes some basic principles to be applied in judgements about specific cases, namely: the **social responsibility of scientists**, the **"no means to harm" principle**, **scientific freedom**, and **collective responsibility for dual-use**.

Social responsibility of scientists

Arising initially in the context of the development of nuclear weapons, discussions concerning the social responsibility of scientists have radically challenged some common ideas in scientific culture, such as the notion that scientists cannot be considered responsible for the malevolent applications of their work (Selgelid, 2010). According to this view, the scientific enterprise is intrinsically good or at least morally neutral. Responsibility falls on those who use scientific knowledge for bad purposes, and on policymakers who fail to prevent them from doing so, while scientists should be considered as innocent.

In recent decades this view has been called into question by the **growing number of research experiments and technologies of dual-use concern**, especially – although not exclusively – in the life sciences, and by the **ever increasing need for scientific knowledge in the production of weapons**. Given the potential of scientific knowledge to result in more harm than good for humanity, the idea has gained momentum that scientists have a kind of **social responsibility for** the **malevolent use of** their **well-intentioned research** (Selgelid, 2010). As **engineers** operate in various areas of scientific research and technology development, and because of the far-reaching implications that their activity may have, they bear social responsibility for the dual-use of their work.

The individual responsibility of scientists/engineers for dual-use consists essentially in **considering the actual and potential applications** that their work could have (Miller and Selgelid, 2008; Selgelid, 2010). According to this view, scientists/engineers are responsible not only for what they **intend**, but also for what they **foresee**, or should have foreseen. In other words, they bear both a **forward- and** a **backward- looking responsibility** for the possible outcomes of their work (Forge, 2008; Forge, 2013).

Forward-looking responsibility means that scientists/engineers have a **moral obligation to foresee**, as far as they can, potential malevolent uses of their findings.	**Backward-looking responsibility** means that scientists/engineers can be held **accountable for having failed to make clear** where their work might lead, which should be considered as **negligence**.

This does not mean that engineers can actually foresee all applications of their work, but that there are circumstances where this is possible, at least to a certain extent. As science funding gives more and more weight to perceived practical benefits, and the gap between "pure" and "applied" research narrows, it is reasonable that it might be possible to look ahead.

"No means to harm" principle

The social responsibility of scientists/engineers incorporates a **"no means to harm"** principle, i.e. the principle according to which it is **morally wrong to provide others with the means to do harm** (Miller, 2013). Providing the means to harm is not synonymous with deliberately doing harm. The distinction is relevant because deliberately doing harm is strongly associated with intentionality, whereas providing the means to harm is related to unintended secondary purpose/use of the engineer's work, in spite of engineer's benign vision at the outset (Kuhlau, 2013; Miller, 2013). Moreover, dual-use dilemmas involve only a presumption of harm, where the harmful outcome is uncertain yet not unthinkable (Kuhlau, 2013).

The principle assumes that:

i. The **research/technology/artefact** in question is a **means to do harm** (where "harm" may refer to physical harm and/or moral wrong, to violation of individual rights, etc.).
ii. And there is a **concrete threat or sufficiently high risk that** the **others** in question, given the chance, **will do harm**.

As such, application of the "no means to harm" principle is a matter of judgement insofar as it requires considered assessment of the nature and likelihood of the potential harm and of the threat/risk.

A crucial condition for including this principle in scientific practice is **awareness** of providing the means to harm and of exposing others to a risk of harm (Kuhlau, 2013). Such depends on the acknowledgement of one's social responsibility as a scientist/engineer, and on one's familiarity with relevant ethical codes and guidelines for the engineering profession. In this sense, those who have the power to assist and oversee scientific work (e.g. professional and scientific associations, universities, peer review journals, etc.) bear a significant responsibility in raising awareness of dual-use issues in engineering (Kuhlau, 2013).

Scientific freedom

The principle of scientific freedom has become increasingly important in discussions about dual-use dilemmas, specifically with regard to the dissemination of research findings (Miller and Selgelid, 2008). This is principally because communication of scientific knowledge in peer-review journals and within the scientific community may increase the risk that malevolent users can gain access to research findings and implement their dual-use potential. For this reason, recent debates around the publication of experiments of dual-use concern (e.g. research on the H5N1 virus) have called into question the unrestricted dissemination of research with potential harmful implications.

In the ethical analyses of dual-use issues, scientific freedom is a key moral value but **cannot be considered as an absolute value** that should take precedence in all circumstances. The principle is grounded in the freedom of intellectual inquiry, a fundamental human right (Miller and Selgelid, 2008). In general, this is not a right that an individual can exercise alone, since interpersonal communication is always required to produce valuable knowledge. In other words, to engage in free intellectual inquiry is to freely participate in discussion with others in order to test one's own and others' reasoning.

Since the emergence of modern science, freedom of inquiry has been essential to scientific research as a cooperative endeavour. As such, the production of scientific knowledge and technological innovation is governed by joint epistemic practices, such as replication of experiments and peer-review processes, to ensure the quality of scientific work and promote its advancement (Miller, 2013). Notwithstanding that uncensored publication is a key-element in the collaborative production of knowledge, the imposition of **limits on the freedom to publish may be justified by overwhelming concerns that risks of harm to others outweigh the expected benefits of disseminating research findings**. For example, where dissemination of knowledge involves a sufficiently high risk of compromising human health and security.

Although highly desirable, a proper balance between scientific progress and security is not straightforward and it is not clear how it could be attained in practice. In contemporary debates about dual-use, a widespread idea is that **responsible actors at different levels** (e.g. individual scientists/engineers, universities and other research institutions, scientific journals, policymakers, etc.) **should undertake to balance the goals of promoting scientific progress and avoiding harm to others** (Selgelid, 2010).

Collective responsibility for dual-use

Dual-use dilemmas raise ethical questions that **cannot be successfully addressed by voluntary self-governance of the individual scientist/engineer alone** (Selgelid, 2010). Scientists/engineers could be exposed to conflicts of interest related to scientific career advancement, such as the imperatives to publish, file patents and transfer research results, even where this may not be in society's best interest. An additional limit to self-governance is that individual judgements and obligations about whether to proceed with research or to publish or transfer research findings depend in part on other intermediaries at different levels of the science governance hierarchy. In fact, scientific activity is a complex cooperative endeavour involving a number of different actors (e.g. university research teams, public and private funders, etc.) having multiple connected goals (Miller, 2013).

For these reasons, **dual-use dilemmas involve** important questions about **more collective responsibilities**, as distinct from individual responsibility, in order to assess and address risks of malevolent uses of scientific work. Such questions concern the **responsibilities of those who have the power to supervise and regulate the work of scientists/engineers** (e.g. universities, professional associations, scientific journals, governments, etc.). For example:

- ✓ **Universities** would be responsible for adopting oversight strategies for research activities that entail dual-use risks, and for providing education to help students and practising researchers to assess these concerns.
- ✓ **Professional associations** should address dual-use issues in their codes of conduct and strive to enforce these codes among their members.
- ✓ **Governments** should decide whether or not to impose restrictions on dual-use research, such as: review and clearance of research by ethics boards, before it is conducted; mandatory education of researchers on the ethical issues of dual-use; or stricter oversight of patenting and export control mechanisms to avoid the transfer of potentially harmful discoveries.
- ✓ **Funders** of scientific research should stipulate that the capacity to address the ethical issues of dual-use is a necessary condition of eligibility for funding on the part of research institutions.

To be effective, harm prevention with regard to dual-use knowledge should be a joint enterprise of individual scientists/engineers and their scientific communities, institutions, non-scientific partners, and oversight organizations.

2.a. Ethical issues in military research

In line with the proposed ethical framework, scientists/engineers should not engage in **military research that has solely malevolent purposes**, such as research on new and better weaponry (Forge, 2012; Forge, 2013). Because it is primarily intended to do harm, offensive military research should be considered as morally impermissible in engineering. The same can be said of military research aimed at producing weapons which has incidental friendly civilian applications, since its primary goal is to serve malevolent purposes.

The problem is more complex with **military research on weapons designed for solely defensive purposes**. The ethical justification of engaging in military research on weapons development for defensive/preventive purposes will depend on the circumstances, and involves thorough consideration of expected benefits and potential dual-use risks (Forge, 2013). For example, the potential harm that can be inflicted should be smaller, or at least commensurate, with that prevented. This judgement is more difficult to support when it comes to making new and improved weapons, since the preventive purpose is accompanied by the risk of providing others with the knowledge/means to harm in an innovative way, thus raising critical dual-use concerns.

Consider the following **examples of defence research** raising dual-use concerns:

- The **US Government Project BioShield**, aimed at developing medical countermeasures against chemical, biological, radiological or nuclear attacks:
  http://georgewbush-whitehouse.archives.gov/infocus/bioshield/index.html
  https://www.medicalcountermeasures.gov/barda/cbrn/project-bioshield-overview/project-bioshield-annual-report.aspx
  This protective non-offensive research program has been widely criticized because its results could also assist malevolent users in the development of new weapons:
- The **Laser Weapon System (LaWS)** currently developed by the **US Navy** and intended for ship-defence to counter unmanned and light aircraft, such as drones or small attack boats:
  http://www.navy.mil/submit/display.asp?story_id=80172

Other critical dual-use concerns arise with regard to **military-civilian research** aimed at the development of technologies with both military and commercial applications. Since the early 1990s, a number of countries have launched a variety of joint military-civilian research programs to this end, including France, Germany, UK, and US (te Kulve and Smit, 2003). Civilian-military integration in developing new technologies may facilitate technology transfer and promote economic interests, but it may also encourage scientists/engineers and policymakers to overlook potential threats to human security.

Individual scientists/engineers should not take upon themselves the entire responsibility of deciding whether or not to engage in military defence research or in joint military-civilian programs. As suggested in the previous discussion, dual-use dilemmas entail important **research policy questions that need to be addressed by all responsible actors concerned** (e.g. the scientific community, universities, governments, etc.).

Public funding agencies may play an important role in the mitigation of dual-use concerns through funding policies that promote peaceful scientific research. An example is the attempt to limit military oriented research undertaken within the EU flagship program Horizon 2020, which restricts funding to research having an "exclusive civil applications focus"[4].

Civil society should also be involved in assessment of dual-use issues of military research. At present, **NGOs** are playing an important role in the negotiation of military applications of research. A recent example is the international coalition of NGOs working to ban the development and use of fully autonomous weapons[5].

[4] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing Horizon 2020 - The Framework Programme for Research and Innovation (2014-2020), Article 16 Ethical principles, 2: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52011PC0809

[5] See: http://www.stopkillerrobots.org/about-us/

3. Suggested policy options from literature review

The previous sections outlined a workable definition of dual-use and an ethical framework to assess dual-use concerns in engineering sciences. This section continues to review **relevant policy options aiming at addressing dual-use dilemmas** and promoting a culture of scientific responsibility.

Education

In order to raise **engineer's awareness** of potential misuse of their work, **education on dual-use issues** should be part of training programmes for students and research staff in science and technology universities (Miller and Selgelid, 2008; Rappert, 2010; The National Research Council, 2011). Enforcement of codes of conduct among members of the research community and established grant-review procedures have only limited effectiveness if they do not go together with training in the identification and management of dual-use concerns.

An important limit to the usefulness of education is that ethical standards and dual-use awareness are highly dependent on the **imperatives and pressures under which researchers work**. In scientific and engineering research, the cultures and reward structures of labs can **reduce the ability of individuals to recognise ethical problems or to act in a way that they judge to be ethically proper**. Therefore any discussion about training programmes should consider what kind of education would best promote a culture of scientific responsibility.

For example, abstract teaching about ethical problem solving that is dissociated from the circumstances in which individuals may act would not carry much weight with them. Instead, **education can be made to matter** if instruction about the ethical issues of dual-use is given with **reference to power relations, pressures and reward structures liable to cause practical conflicts and dilemmas**.

Constraint of dissemination

Where a sufficiently high risk exists that research findings can be used to serve malevolent purposes, restrictions in the dissemination of findings (e.g. in scientific journals, conferences, etc.) may help to reduce this risk (Miller and Selgelid, 2008).

As discussed in **part 2**, the question of whether dual-use knowledge ought to be censored or freely disseminated is extremely complex. On the one hand, excessive oversight of scientific enterprise might interfere both with the right of freedom of inquiry and, in the case of censorship of potential dual-use discoveries, with freedom of speech. Excessively heavy regulation could also be counterproductive in the sense of placing curbs on beneficial research. On the other hand, insufficient control might promote scientific progress while allowing the malevolent use of research findings and, possibly, compromising security. Constraint of dissemination of research findings is further complicated by the fact that the reward system for career advancement in science is almost exclusively dependent on publication.

A **middle-course policy between censorship and free dissemination of dual-use knowledge** might be to disseminate in a way that research findings could not possibly be replicated, and to restrict the possibility of replicating results to authorized researchers (e.g. those with adequate security clearance).

Such a policy would not be without problems, since it may slow down the process of scientific verification. Moreover, this policy requires the definition of consensus criteria for authorization to replicate results, and would necessitate the development of an alternative reward system for the scientists involved. Arguably, the implementation of this policy will depend essentially on the initiative of scientific journals, or at least require their collaboration, and of scientific institutions responsible for research oversight (e.g. universities, funding agencies, etc.).

Impermissible research

A **more controversial policy** measure would attempt to identify lines of research which have greater potential to be used for malevolent purposes and should not be allowed. The basic assumption behind this proposal is that potentially harmful consequences of dual-use research derive from **cumulative developments in knowledge and technology** enabling new possibilities for action, rather than from single-research inputs (Rappert, 2010). Thus, rather than focusing dual-use assessment exclusively on particular research projects, it would be more helpful to **determine research directions which ought not to be undertaken/funded**. An example of a research field that is currently called into question is research on lethal autonomous weapons systems[6].

Although it may help to mitigate dual-use concerns, this selective policy is at odds with the value of scientific freedom and with the mission of academic institutions, and could be perceived as too intrusive/restrictive by scientists. Its implementation and effectiveness will depend on the establishment of a consensus on what should count as impermissible research, and on the compliance of the scientific community.

Safety and security regulation

Regulations on the safety and security of the research environment (e.g. storage, transport and access to samples of pathogens, equipment, laboratories, etc.) should be **established by governmental agencies**. This policy measure specifically pertains to **dual-use research in the life sciences and in some areas of converging technologies** (e.g. nanotechnology, synthetic biology, biophysics, etc.), where biosafety and biosecurity concerns may arise. **Science and technology universities** have a **key-role role in the application of these regulations**, through the adoption of effective oversight of research activities (e.g. biosafety committees of experts accountable to the government).

[6] See: http://www.stopkillerrobots.org/about-us/

In 2012, the American Association for the Advancement of Science (AAAS), in collaboration with the Association of American Universities (AAU), the Association of Public and Land-grant Universities, and the Federal Bureau of Investigation (FBI), organised a series of policy meetings with research, policy and security stakeholders to discuss options for the oversight of biosafety and biosecurity risks in biological research. These meetings culminated in the publication of two reports (AAAS et al., 2012a, 2012b), including examples of institutional processes for dual-use review[7], and several policy suggestions of relevance to scientific and engineering research in general. In particular, two policy options outlined in the reports are worth considering, since they advocate more cooperative strategies between stakeholders, and public engagement with dual-use issues in scientific research:

Cooperation between the scientific community and government agencies

AAAS et al. reports focus specifically on how to assess and minimize dual-use issues in biological research. Thus, they advocate **cooperation between scientific, public health and security communities**, with a view to **sharing relevant information** about the management of biosecurity risks.

Within this cooperative endeavour, **public health and security agencies** should provide scientists with information on policy concerns, so that scientists can understand the broader security context in which they work. On the other hand, **scientists/engineers** should provide expert input to health and security agencies so that they can more effectively assess and address security risks. This collaborative environment could also benefit from the **input of academic institutions**, which should educate policy experts about the value of academic freedom and inform them of the challenges they face in research and technology transfer.

It is possible to adapt this measure to areas of science and engineering other than biological research by involving the scientific community and those government agencies more concerned with dual-use issues in a cooperative approach.

Public outreach

Scientists/engineers should **reach out to the public and open a dialogue between science and society in relation to dual-use issues of concern**. Scientists should also encourage and actively engage in the **development of education programs in schools and other public forums** (e.g. scientific museums, universities, etc.) where citizens can gain an awareness of areas of scientific research in which dual-use issues arise.

Science and technology universities have a **key-role in supporting public outreach on dual-use issues**, since they can provide the necessary resources and facilities.

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[7] Cf. AAAS et al., 2012b, pp. 14-15: "Boston University's Dual Use Research Review Process", "The University of Wisconsin-Madison's Dual Use Review with Select agent Research".

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