The Regulation of Civilian Drones' Impacts on Public Safety

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This is the third in a series of papers on drones: 1, 2, 3, 4

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Abstract

Because they are airborne artefacts, drones embody threats to people and property, even in normal operation, but especially when malfunctions occur in equipment or in the data communications on which they are heavily dependent. Some natural controls exist over inappropriate drone behaviour. General liability laws provide remedies for harm that arises from drones, and act as a deterrent against irresponsible behaviour. Specific air safety laws do, or may, apply to drones. Co-regulatory mechanisms provide some protections, as may industry and organisational self-regulation. However, a review of current and emergent regulatory arrangements identifies a considerable range of gaps and uncertainties that need to be addressed, particularly in relation to small drones.

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1. Introduction

This is the third in a series of four papers that together identify the disbenefits and risks arising from the use of drones, and consider the extent to which they are subject to suitable controls. The first paper focused on the attributes of drones, distinguishing those that are definitional. It also examined a number of application-areas, in order to reveal the issues that arise in particular contexts. The second paper completed the foundations for the regulatory analysis, by reviewing existing, critical literatures, in order to ensure that the accumulated understanding of relevant technologies is brought to bear on the assessment of drone technologies as well. The technologies in focus are computing, data communications, robotics, cyborgism and surveillance.

Drones have potential impacts and implications across a wide range of areas (EPIC 2005, 2013, Elias 2012). The possibility exists of negative economic impacts, such as job displacement, and consequential impacts on the distribution of income, arising from what is in part a further step in the progress of automation. Behavioural privacy is very likely to be negatively affected by the increased incidence of surveillance of individuals. Where observations achieved using drones are recorded, a further negative impact on data privacy is likely. As noted in the second paper in this series, it has even been argued that drones may exacerbate an existing trend towards de-humanisation. Each of these impacts raises questions about the accountability of the individuals and organisations that operate drones, and that utilise their capabilities.The fourth paper in the series focuses on the use of drones for surveillance, examining psychological, social and political interests that may be threatened by the use of drones, including the freedoms of movement, association, speech and thought, and the interest that individuals have in controlling the use of information about themselves.

The focus of this paper, however, is on public safety issues related to the use of drones for civilian purposes. In particular: What exists to encourage the inclusion of sufficient safety features within drone design, and to cause drone operations to be conducted with appropriate care? And what are the legal consequences when readily-avoidable harm arises from drone usage?

The application of drones in civilian contexts creates the prospect of a wide range of benefits. It also creates new sources of harm through interference, accidents and violent action. Most incidents reported to date have resulted in little or no harm to the public (e.g. BBC 2011 in the UK, Carrigan et al. 2008 and T&D 2012 in the USA, Mortimer 2012 in New Zealand, and Kontominas 2013, LL 2013 and Crozier 2013 in Australia). On the other hand, in one case in the Congo the crash-landing of a drone resulted in a death (La Franchi 2006), and another death in Korea resulted from pilot error following loss of the GPS data-feed (Marks 2012). A moderate number of near-misses have been reported, most graphically over Kabul in 2004 (Spiegel 2013).

Of course, drones are not the first potentially hazardous objects using airspace. There are therefore many existing legal rules that are designed to achieve air safety and provide for compensation where harm does result. Beyond formal rules, there is a variety of regulation that seeks to encourage the safe use and design of products in general and objects using airspace in particular. Section 3 draws on some of the regulatory theory literature to establish a framework for the discussion and sections 4 and 5 then consider the extent to which existing regulation satisfactorily addresses drone-related safety problems.

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2. Drones as Risks to Public Safety

This section draws on the first two papers in the series in order to identify the ways in which the design and deployment of drones can give rise to harm to people and property. It then considers the extent to which natural controls mitigate the risks, and identifies the residual risks that need to be addressed.

2.1 Threats

The field of risk assessment uses the term `threat' to refer to intentional, accidental or environmental events that, by impinging on some vulnerability, tend to result in harm to an asset. In common with other aircraft, drone flights give rise to potential harm to public safety through direct impact of the drone or its payload on some other object or person. In addition to direct harm, an impact can lead to explosions or fires, resulting in further damage. The kinetic energy of an impact is a primary focus in the literature (e.g. Clothier et al. 2010). However, many drones have rapidly moving parts, in the form of propellors, which are capable of causing much more substantial physical and mental trauma than the drone's mass and velocity alone suggest.

It is not only physical impacts that threaten assets. An out-of-control drone may surprise individuals in its vicinity, in some cases leading to accidents e.g. where a driver of a motor vehicle, or the pilot of another drone, loses control their vehicle or performs a dangerous avoidance manoeuvre. In addition, drones depend on continual feeds of data and commands, which makes them a source of interference with the electromagnetic signals on which other devices depend. This may in turn impair the functions of other devices.

Harmful incidents stem from a wide variety of causes. Some forms of harm may be caused deliberately, and indeed harm might be the purpose of a drone's use. A drone may deliberately drop its payload to cause harm or it may be employed on a `kamikaze' mission. On-board equipment, such as a transmitter, may be used to intentionally disrupt other activities. Motivations for deliberate harm include thrill-seeking, revenge, aiding some other criminal act, and terrorism.

It need not be the drone's owner or operator that intends the harm to be done. A drone may be hijacked, and its behaviour controlled by someone other than the original pilot. Alternatively the pilot's control over the drone's behaviour may be compromised, through signal jamming, falsification of a data-feed, interference with the control-feed, interference with software used by the drone or the pilot, or physical threat to the pilot. A drone's behaviour may be affected not only by electronic means but also directly, by physical attack using a projectile, including attack by another drone. Recent reductions in drone costs have been so significant that the capital needed to mount attacks is very low, and the drones themselves are expendable. Indeed, the costs are so low that the motivation for drone-hijacks is more likely to be to obscure the hijacker's identity then to avoid the expense of acquiring a drone.

Much more common that such attacks are likely to be incidents that are unintended but foreseeable consequences of drone deployment. All drones, but especially inexpensive ones, suffer component failure, often during flight. Pilot error, electromagnetic interference or technical malfunction during a landing attempt may cause a crash, resulting in harm to people or property. In the case of substantially autonomous drones, errors may result from a drone encountering unplanned circumstances or due to programming errors. Some further drone malfunctions will be a result of environmental incidents such as severe turbulence and lightning, in insurance parlance `Acts of God', which are foreseeable but unpreventable.

Most of these circumstances can arise with manned aircraft. For example, although interference with software is a particular challenge for drones, any airborne vehicle is at risk of sabotage. The most significant differences between drones and non-drones are not in the fact that harm can occur, in the types of harm that might occur, or in the range of people who might be responsible for such harm. The key factors are the low costs of the technology - which arise in part from the limited extent to which safety-related features are included, the consequential high volume of drone activity that can be reasonably anticipated, the inevitably lower standards of pilot performance, and the high costs involved in detection, investigation, and sheeting home responsibility.

Safeguards against drone incidents are likely to be considerably more challenging than for conventional aircraft. As airspace becomes more congested, the risk of collisions increases.. Physically congested airspace will also be electronically congested, resulting in high levels of signal interference and hence unreliable and intermittent data- and control-streams. In controlled airspace, drones create new challenges for the interactions between pilots and air traffic controllers. Under current arrangements, those communications can rely on direct `line of sight' transmissions. Communications with drone-pilots, on the other hand, are likely to be less direct and hence dependent on additional infrastructure, which represents points-of-failure, increases latency, and may threaten the engrained expectation that pilots respond to controllers' instructions within seconds.

With the low costs of most micro-drones come low standards of hardware and software quality assurance. Large drones for industrial and commercial purposes involve substantial investment, including to some degree in quality. Military standards are high for some purposes, but lower for others because expendability is an engrained assumption. On the other hand, software for micro-drones generally, and particularly for the small business, consumer and hobbyist markets, is likely to reflect the shoddy standards and the 'rapid application development', 'permanent beta' and 'crowdsourced documentation' mentalities that are prevalent in consumer software and services. Software quality assurance, readability, maintainability, audit and certification are concepts foreign to those fields. The result is a significant level of risk of harm arising from malfunction.

Piloting requires occasional, rapid and finely-judged responses, amidst long periods of boredom. Interruptions and lapses in concentration appear far more likely in the case of remote rather than onboard pilots. Some contexts involve complex environments that contain obstacles, other drones, and other activities, where not all of the desirable contextual information is available, and where value judgements and cultural understanding may be needed. The physical, personal and organisational distance that separates the drone's pilot and facilities operator(s) from the drone's behaviour may therefore be an important factor in the safety of drone activities. Three points on the distance scale can be usefully distinguished:

- **an adjacent pilot**, who retains a degree of association with the activity, and is close to the location in which the drone is operating, and hence is likely to have a reasonable appreciation of the prevailing conditions and of relevant national, regional and local cultures. This is associated with Visual Line of Sight (VLOS) operations
- **a remote pilot**, who is much more likely to lack a sense of immediacy, involvement and personal responsibility, but who still brings with them an appreciation of limiting factors, such as the ambiguity of data, and the impact of their actions on other people
- **a substantially autonomous drone**, whose upper-level functions - such as the determination of destinations, flight-path planning, operation of onboard equipment, and delivery of payload - are performed without direct oversight by a human pilot, and perhaps without any realistic scope for intervention by a human, or even resumption of control by a human

Further challenges arise because micro-drones are much less obvious than piloted aircraft, and can be designed to be not readily detectable. As nano-drones emerge, they will be even less apparent. Very small drones are being conceived to be used in swarms, with individual devices redundant and highly-expendable, and largely or even entirely autonomous. In addition to their promise in such areas as environmental surveillance, they harbour considerable threats even when intended for beneficial or benign purposes, and even greater threats when used with harmful intent.

While autonomous drone operation avoids the issues associated with pilot concentration, it is very challenging to design and program a device to cope with unplanned shortage of data, and to recognise out-of-bound conditions and revert to fallback or fail-soft arrangements, such as to alert the pilot to switch back to manual control. Situational value-judgements, meanwhile, are simply beyond-scope.

An indication of the extent of these challenges is the slow progress made with driverless cars. These operate in a two- rather than three-dimensional environment, which is far more structured, has far fewer degrees of freedom to cope with, and for which fallback and fail-soft measures are much more easily specified and implemented. Driverless cars nonetheless have not yet overcome problems of cost, contextual complexities and uncertainties, and the challenges of driver-override and switching from autonomous to manual control (Knight 2013).

2.2 Natural Controls

Risks may be held in check by a variety of factors. Natural controls that constrain unreasonable behaviour by drone manufacturers and operators need to be taken into account when considering the extent to which regulatory measures are necessary. The natural controls might even be sufficiently effective, and the residual risk sufficiently limited, that active regulatory measures could be unnecessary.

In the case of manned aircraft, physical danger operates as a natural control. Danger arises from air instability caused by weather conditions, fire and volcanic eruption. Other sources of danger include congestion in the airspace and in airwaves of the relevant frequencies. Danger to the pilot's personal safety mostly acts as a strong deterrent against irresponsible behaviour, and that is reinforced by the potential financial consequences. In the case of drones, however, the pilot is not on board. Hence, while not irrelevant, the risk of harm to the drone operator will seldom represent a sufficient protection against harm to the public.

In many circumstances, economic considerations are an effective form of natural control. The cost of manned aircraft is sufficiently high to represent a substantial constraint on their purchase and use. An associated factor is the considerable infrastructure necessary to support aircraft take-off, operation, landing, fuelling, housing and maintenance, all of whose costs are borne by the aircraft operator. Organisations and individuals that operate aircraft need access to considerable financial means. They are readily discoverable , and hence there is a reasonable prospect that such organisations can be held accountable. The insurance industry may play a constructive role, by communicating the level of financial risk to aircraft operators, and by declining to quote a price where an operator's practices are uninsurably unsafe.

Economic forms of control may therefore be reasonably effective natural controls against inappropriate use of large drones, and perhaps even in relation to the smaller categories of drones where they are operated by organisations that are large and visible. On the other hand, mini-drones, and particularly micro-drones, are inexpensive, can be acquired by people and organisations with limited means and limited visibility, and require little or no specialised infrastructure. Operators of such devices are far less likely to be discoverable and held accountable for harm that they may cause. Economic factors are therefore an ineffective control for many and possibly most instances of use of the smaller categories of drones.

A further possibility is reputational controls, through `the court of public opinion', reinforced by media reports and opinion-pieces in official and unofficial media. These have some degree of impact on large organisations, particularly consumer-facing organisations for whom public image is important to customer loyalty. The effect may be greater in highly competitive marketplaces, where reputation is critical to achieving and sustaining market-share. On the other hand, seriously harmful impacts from bad publicity may be too sporadic to represent a significant deterrent against irresponsible drone usage.

The attitudes of customers of drone-using organisations might act as a curb on unreasonable behaviour, for example where a single major player has significant market power. Alternatively, a collective of smaller customers and even of individual consumers may be able to achieve considerable influence over suppliers. Beyond customers, other stakeholders may have institutional power, and residents within an area affected by drone usage may take effective collective action such as well-publicised complaints, boycotts, demonstrations, and attacks. Instances of such countervailing power tend to be exceptions, however, rather than the norm.

Independently, and even considered together, it does not appear that natural controls are likely to be sufficient to ensure that the threats that drones present to public safety are kept in check. The following section summarises the residual risks and their implications.

2.3 Residual Risks

The conduct of a risk assessment results in the identification and prioritisation of a set of risks that are not satisfactorily addressed by either natural controls or such safeguards as are already in place. Because civilian uses of drones are only in their infancy, there are relatively few examples of harms caused by drones to date. In Australia, for example, no media articles appear to have yet surfaced of any collisions between drones and commercial or military aircraft, nor of any incidents that have given rise to death, injury or material harm to property (other than to the crashed drone itself). There have, however, been sightings of drones in the vicinity of airports, in particular at Perth airport in 2009, by a naval pilot at Jervis Bay in November 2011, at Sydney airport in February 2012, and by a commercial helicopter pilot, date unknown. In October 2013, two incidents were reported, each resulting in criticism of the drone pilot, but no apparent sanctions. In one case, a micro-drone collided with the Sydney Harbour Bridge (Kontominas 2013), and in the other a drone was flown close to bush-fire-fighters and a water-bombing helicopter (Crozier 2013).

The situation is similar in the United States. A quotation from the USAF Chief of Staff in 2005 disclosed that "We've already had two mid-air collisions between UAVs and other airplanes [in Iraq], we have got to get our arms around this thing" (quoted in Peterson 2005, p. 4). Three years later, on the US mainland and in the civil jurisdiction, "UAS could not meet the aviation safety requirements developed for manned aircraft and ... this posed several obstacles to safe and routine operation in the national airspace system. [In 2012,] these obstacles still exist and include the inability for UAS to sense and avoid other aircraft and airborne objects in a manner similar to manned aircraft; vulnerabilities in the command and control of UAS operations; the lack of technological and operational standards needed to guide safe and consistent performance of UAS; and final regulations to accelerate the safe integration of UAS into the national airspace system" (GAO 2012, pp. i. See also p. 14).

A review of the literature evaluating the safety of large military drones in comparison with aircraft operating in commercial airspace shows that they have suffered markedly more frequent mishaps, especially during take-off and landing (Armstrong 2010). That work concluded that "electrical and mechanical reliability ... were as significant as human errors in the causes of accidents", and "a combination of design features are required to drive accident rates down to equivalent levels of safety to general aviation safety levels [including] dual channel, digital flight control system and redundant communications, ... [redundant] safety critical systems, [automation of] take off and landing ... [and] procedures and training for operators and [pilots]" (pp. 12-13).

Small drones feature significantly less investment in safety features and manufacturing quality assurance than is the case with large drones. The likelihood of malfunctions and incidents is accordingly far higher per flight-hour, and, because of their inexpensiveness, functionality and popularity, the volume of flight-hours of intrinsically unsafe small drones appears very likely to far exceed those of large drones.

The natural controls discussed above do not represent sufficiently effective safeguards, and considerable residual risks exist. Although reported incidents are few, drone activity appears set to increase rapidly in the near future, and incident volumes are likely to grow exponentially with traffic. An examination of regulatory arrangements is clearly warranted.

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3. Regulation and Technological Change

Because `regulation' is capable of many interpretations, it requires some exploration. The term 'regulation' encompasses both formal laws and `soft law' (e.g. Rip 2010). One definition of `regulation' is "the sustained and focused attempt to alter the behaviour of others according to standards or goals with the intention of producing a broadly identified outcome or outcomes, which may involve mechanisms of standard-setting, information-gathering and behaviour modification" (Black 2008, Brownsword & Goodwin 2012). The Australian National Audit Office has defined regulation as "instruments used ... to influence or control the way people and businesses behave in order to achieve economic, social or environmental policy objectives" (ANAO 2007). These definitions exclude natural controls such as those discussed above, and focus on deliberate attempts to achieve particular outcomes by influencing behaviour.

A large body of theory exists relating to regulatory mechanisms (Braithwaite & Drahos 2000). During the second half of the 20th century, a regulatory scheme involved a regulatory body that had available to it a comprehensive, gradated range of measures, in the form an 'enforcement pyramid' or 'compliance pyramid' (Ayres & Braithwaite 1992, p. 35). That model envisages a broad base of encouragement, including education and guidance, which underpins mediation and arbitration, with sanctions and enforcement mechanisms such as directions and restrictions available for use when necessary, and suspension and cancellation powers to deal with serious or repeated breaches.

Since the 1990s, however, the scale, power and supra-nationalism of corporations, combined with the mantra of economic growth, have driven a widespread relaxation of controls and the avoidance of the creation of additional fetters on corporate freedom to innovate. The notion of `governance' has been supplanting the notion of `government', and Parliaments and Governments have increasingly withdrawn from the formal regulation of industries (Scott 2004, Jordan et al. 2005). Reflecting the switch from `government' to `governance', the literature of the last two decades has focussed on deregulation, through such mechanisms as `regulatory impact assessments' designed to justify the ratcheting down of measures that constrain corporate freedom, and euphemisms such as `better regulation' to disguise the easing of corporations' `compliance burden'.

In this paper, four forms of control are considered in addition to the natural controls discussed above. The four regulatory forms are depicted in Table 1, which draws on Jordan et al. (2005).

Table 1: Regulatory Forms and Regulatory Actors

Forms:	Formal Regulation (‘Government’)	Co-Regulation	Industry Self-Regulation	Organisational Self-Regulation (‘Governance’
Actors:				
The State	**Determines What and How**	**Negotiates What and How**	Influences What	Has Limited Influence
Industry Assocn	Influences What and How	**Negotiates What and How**	**Determines What and How**	Influences What and How
Corporations	Contribute to Industry Assocn	Contribute to Industry Assocn	Contribute to Industry Assocn	**Determine What and How**
Other Stakeholders	May or May Not Have Some Influence	May or May Not Have Some Influence	May or May Not Have Some Influence	May or May Not Have Some Influence

Formal Regulation is normally implemented as laws, and the other forms are sometimes referred to as `soft law'. As the following sections demonstrate, aircraft operating in `controlled airspace', or elsewhere but for commercial or other work purposes - irrespective of whether they have an onboard pilot - continue to be subject to formal regulation or `government', although the laws are subject to varying degrees of enforcement. On the other hand, the limited regulatory frameworks applicable to model aircraft and small drones used for other purposes are commonly at the very mild end of `soft law' or `governance'.

One challenge in evaluating a regulatory regime is the determination of its scope, including what activities are subject to it, what parties are regulatees, and what parties are beneficiaries. Typically, this is done by defining particular conduct or a particular industry or sector. Neither industries nor conduct are static, however. Technological, economic, social and political factors change the forms of conduct in which parties engage, alter industry structures, and generate new industries.

Few new technologies get a free ride, unconstrained by regulation. As will be demonstrated in the following section, drone technologies are subject to a range of regulatory measures that were created without drones specifically in mind. Many laws are broadly phrased, and operate in a more or less technology-neutral fashion. Tort law and product liability rules are broadly applicable and have regulatory effects on the manufacture and use of not only existing products but also new ones. Relevantly to the present topic, many laws governing the use of airspace are expressed in language that includes drone activity, despite the fact that those laws were created for the primary purpose of regulating aircraft with onboard pilots.

A crucial question when considering an existing regulatory regime in the context of new forms of conduct (such as drone flight) is the problem of `regulatory connection' (Brownsword 2008). Current laws and regulatory approaches, which were designed for the technological landscape of the past, require constant `reconnection'. In some contexts, drones may be in a regulatory void with very little control over particular conduct. In other circumstances, the regulatory regimes designed for older technologies may fail to achieve their purposes in the new context.

There are different ways of classifying the problems that may arise. We apply the theoretical lens developed by one of us in Bennett Moses (2007), which assists in considering the fit between an existing regulatory regime and new forms of conduct. This identifies the following elements:

- The need for special rules to deal with a new situation
- Uncertainty as to how the law applies to new forms of conduct, in particular:
  - uncertainty as to how a new activity, entity, or relationship will be classified
  - uncertainty where a new activity, entity, or relationship fits into more than one category, so as to become subject to different and conflicting rules
  - uncertainty in the context of conflicts of laws
  - uncertainty where an existing category becomes ambiguous in light of new forms of conduct
- Over-inclusiveness and under-inclusiveness
  (also described as problems of targeting in new contexts)
- Obsolescence, where:
  - conduct regulated by an existing law is no longer important
  - a rule can no longer be justified
  - a rule is no longer cost-effective

In order to evaluate the effectiveness of particular regulatory regimes, a set of evaluation criteria needs to be established. The factors identified in Table 2 were developed by reviewing a range of material that was published over an extended period and with varying purposes in mind. Hepburn (2006) and ANAO (2007) were of particular value.

Table 2: Criteria for the Evaluation of a Regulatory Regime

Process

- **Clarity of Aims and Requirements**
  Purposes and obligations are understandable by regulatees and beneficiaries
- **Transparency**
  Development and review processes are open, and requirements are published
- **Participation**
  All stakeholders are involved in development and review processes
- **Reflection of Stakeholder Interests**
  The needs of beneficiaries are addressed, and the legitimate interests of regulatees reflected

Product

- **Comprehensiveness**
  All relevant aspects are encompassed within a coherent framework
- **Parsimony**
  The regime is no more onerous or expensive than is justified
- **Articulation**
  The requirements are sufficiently specific and operationalised, to enable effective and efficient implementation by regulatees
- **Educative Value**
  Requirements are expressed in explanatory and instructive form, rather than in abstract, discursive prose
- **Appropriate Generality and Specificity**

The scope and the requirements are sufficiently general to cover reasonably foreseeable future developments, but sufficiently specific to avoid over-inclusiveness and anomalies

Outcomes

- **Oversight**
  Regulated behaviours are subject to monitoring
- **Enforceability**
  Regulated behaviours are subject to enforcement actions, by beneficiaries directly, and by an enforcement agency
- **Enforcement**
  The enforcement agency has appropriate powers and resources, and uses them in order to achieve compliance
- **Review**
  The scheme is reviewed and adapted to ensure that the outcomes correspond to the aims

This paper considers regulation that has the effect of protecting public safety in the context in which drones operate. This includes specific air safety regulation, but also generally applicable laws. The scope of the regulatory scheme needs to encompass all parties whose behaviour may result in threats to public safety. Within the user sector, this includes pilots, operators of facilities carried by drones, employers of pilots and facilities operators, and legal persons contracting for or otherwise stimulating the use of drone-based services. Relevant entities in the producer sector include manufacturers, retailers, configurers, installers, maintenance contractors and inspectors.

The following sections assess the extent to which each of the four regulatory forms identified in Table 1 satisfies the public need for dealing with public safety risks arising from drones.

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4. General Laws Affecting Public Safety Aspects of Drones

Drones do not 'come naked into the world', but bearing legal clothes. This section first applies the concepts commonly used in risk management theory to distinguish a range of approaches to managing risks, and then shows the manner in which existing laws may contribute to limiting harm arising from drones. Because laws of the relevant kinds vary considerably among jurisdictions, a description is provided of the heads of law applicable in a single country, Australia, in which the authors are resident, with consideration then given to the extent to which laws elsewhere are similar to, and differ from, those in Australia.

4.1 Risk Management

The basic concepts and processes of risk assessment and risk management are so well-estabilshed that they are subject to multiple formal Standards, and supported by multiple proprietary products. The outcome of these processes is a risk management plan, which identifies existing safeguards that are to be adapted and additional safeguards that are to be implemented, in order to address the residual risks that are identified as being of primary concern.

The many approaches that can be adopted to addressing risks can be usefully grouped into three generic strategies. Proactive strategies include avoidance (e.g. choosing not to use inherently dangerous materials such as hydrogen in balloons and nuclear reactors in aircraft), prevention (e.g. through the application of the redundancy principle to power sources and communications links), and deterrence (e.g. sufficiently frequent communication to pilots and facilities operators of the personal consequences of breaches of operating standards).

Reactive strategies, on the other hand, are 'post-controls', operating after the event, as mitigating factors. Isolation measures are concerned with damage-limitation. Recovery refers to the means used to regain the conditions that would have existed if the incident had not occurred. Transference diverts the harm elsewhere, for example by claiming against an insurance policy.

The third cluster comprises Non-Reactive strategies. These are tolerance of the harm (e.g. through active self-insurance, by setting aside a budget each period), abandonment (e.g. putting up with the loss), dignified demise (e.g. orderly close-down of the entity's drone business in a controlled manner when its first drone crash occurs) and graceless degradation (e.g. uncontrolled bankruptcy when the entity's first drone crash occurs).

A variety of regulatory arrangements exist that are of the nature of a transference approach to risks, through the assignment of liability for loss. Through warranties, compensation schemes, liquidated damages clauses, negotiated settlements, arbitration and litigation, an organisation that suffers harm may be provided with some amount less than the harm they suffered (partial restitution), about the same as they suffered (recompense), or more than they suffered (e.g. through aggravated damages).

Such regulatory arrangements may, in addition to representing the reactive strategy of transference, encourage proactive strategies. A law that imposes financial responsibility on the party that causes harm leads that party to internalise the costs of their conduct. For this to be the case, however, such laws must be sufficiently well-known to the party causing the harm, and the party must be discoverable, and must be subject to the relevant processes of law (e.g. be within the jurisdiction), and must have sufficient assets within the jurisdiction, and the costs involved in the process must not be unduly high, and the delays that occur naturally and through contrivance must be not unduly long, such that a credible threat exists. Imposing criminal responsibility for inappropriate behaviour also has the effect of encouraging the adoption of proactive strategies. In the case of drone manufacturers and users, it will often be the case that these criteria are not satisfied. As discussed earlier, the low cost of mini- and micro-drones enables their operation by companies or individuals that may be judgement-proof.

The next section identifies laws that in effect implement the reactive strategy of transference through the creation of liabilities, and the subsequent section considers the effects of relevant criminal laws.

4.2 General Liability Laws

A range of laws may contribute to the protection of public safety against actions by drones, by drone pilots and facilities operators, and by people who hijack drones or interfere with drone controls. The primary such laws are product liability and negligence. Laws relating to liability for harm arising from impacts by aircraft and items falling from aircraft are addressed in a later section.

Manufacturers and other parties in the supply chain may have responsibilities under product liability laws. While the precise form of the law of product liability (and therefore the precise legal issues that arise) differ between jurisdictions, laws in Australia, the United States and Europe provide similar general constraints on defective manufacture. In Australia, Part 3-5 of the Australian Consumer Law, ss.138-150, provides for manufacturer liability where goods supplied in trade or commerce have a safety defect that results in injury or, in some cases, property damage. Safety of consumer goods is also subject to Part 3-3, ss.104-108. In Europe, Directive 85/374 on Liability for Defective Products provides for compensation for damage caused to the physical well-being or property of individuals as a result of a defective product. The law of product liability in the United States varies by State, but general principles can be found in the Restatement of the Law (3d) of Torts: Products Liability.. The challenge for those harmed by poorly designed and manufactured drones is in proving that there is a `defect' within the meaning of the laws of the relevant country.

Whereas product liability laws focus on the responsibility of manufacturers for defective products, negligence creates liability for a broader range of actors. For example, if a party using a drone is found to have a duty of care in relation to another party, and if the first party acts in a way that is found to have breached that duty and thereby causes injury or damage to the second party, then the first party may be liable under the tort of negligence. The liability may fall on an adjacent party, such as the employer of an employee who acted negligently. Although there are differences, negligence law has similar regulatory effects in all common law countries. Within civil law jurisdictions, the rather different concept of `delict' (which takes varying forms in different civil codes) may also create liabilities where parties engage in some forms of negligent conduct.

The strength of the regulatory signal sent by product liability and negligence laws is subject to debate. In both cases, the regulatory benefits are of particular importance where a technology is new, when technology-specific strategies for managing risk are less likely to exist. Thus tort law is argued to be a useful social learning and feedback mechanism in the early stages of a new technology's use (Lyndon 1995). Even those who argue that the (economic) case for product liability as practised in the United States is "uneasy", recognize its importance where markets are not well established and existing regulation is not effective (e.g. Polinsky and Shavell 2010).

This is not to say that the regulatory signals sent by general mechanisms such as product liability and negligence law will be as clear as those that may be set out in more specific regulatory regimes. Tort law may deal poorly with problems that involve multiple competing variables, as arises with drone design and operation. A court may find that a manufacturer or user is liable, but will not prescribe how a particular design feature or activity would need to be modified in order to avoid liability. Further, a court will be of no assistance in deciding what to do if making such a modification would generate different risks or disbenefits. Courts do not seek to evaluate design or use as a whole - they provide a simple answer in relation to a particular past practice. Even when examining historical circumstances, courts are in a poor position to evaluate engineering decisions in their entirety (Bazelon 1986). Judges are not in a position to perform the kinds of risk assessment exercises that might be undertaken by a regulatory body, an industry body or an industry player.

Further, tort law assumes a single person is responsible for causing harm. In the context of the US law of product liability, difficulties arise in assigning liability among the multiple parties involved in the context of `open' robotics, where the original product adopts a modular design that allows for its use in combination with hardware or software designed and manufactured by an independent party (Calo 2011). Those issues arise in relation to drones, because drones are a form of robot, and they may be manufactured, assembled, programmed, owned and operated by different legal persons.

For product liability and negligence to be effective transference or deterrence mechanisms, those harmed must have a real ability to bring proceedings against manufacturers and operators of drones, and this must be perceived as a risk by those manufacturers and operators. The costs of bringing legal proceedings, delays in the court system, including through successive interlocutory actions, hearing at first instance, and appellate processes, and uncertainties inherent throughout the litigation process, tend to undermine that ability, and hence create doubts about the effectiveness of general liability laws. This is particularly so where new technologies such as drones are involved because of the uncertain application of unclear law to unfamiliar facts.

4.3 Criminal Laws

Criminal laws, where they apply, may not achieve any transference effect, but may be a stronger deterrent than the risk of civil proceedings. This section considers two sets of laws, relating respectively to violent acts and to computing and data communications.

(1) Laws Relating to Violent Acts

Where a drone is used, or is interfered with, with the intention of causing harm to a person or property, various criminal laws relating to acts of violence may be applicable. Such laws may also apply where an attack is mounted on a pilot or facilities operator, or premises or a vehicle from which they are operating. Under the Crimes Act 1900 (NSW), for example, offences relevant to intentional violence include:

- wounding or grievous bodily harm (s.33 - penalty up to 25 years imprisonment)
- assault occasioning actual bodily harm (s.59 - 5 or 7 years)
- assault not occasioning bodily harm (s.61 - penalty 2 years)

Offences relevant where harm arises without intent include reckless grievous bodily harm or wounding (s.35 - 10 years) and causing grievous bodily harm by any unlawful or negligent act (s.54 - 2 years).

A useful comparison is offences arising in relation to the control of `a vehicle' (a term that would appear not to encompass drones), for which relevant laws include:

- dangerous driving occasioning death (s.52A - 10 years)

- dangerous driving occasioning grievous bodily harm (s.52A - 7 years)
- furious driving that does or causes to be done to any person any bodily harm (s.53 - 2 years)

In relation to 'driving' offences by pilots, such as dangerous piloting occasioning death, bodily harm or damage to property, the NSW criminal law appears to defer to Commonwealth provisions. The Civil Aviation Act 1988 (Cth) makes it an offence to operate an aircraft being reckless as to whether the manner of operation could endanger the person or property of another person (ss.20A, 29 - 5 years).

Under the Crimes Act (NSW) s.154B, unlawfully exercising control of an aircraft is a form of larceny (7 years). Destruction of, or damage to, an aircraft with intent to cause death of [any?] person or with reckless indifference for the safety of [any?] person is an offence under s.204 (25 years). Also of relevance is prejudicing the safe operation of an aircraft (s.205 - 14 years). Under s.4, 'aircraft' "includes any machine that can derive support in the atmosphere from the reactions of the air", and hence includes drones. On the other hand, there is some general uncertainty in that it is not clear under what provision it is an offence to intentionally or recklessly harm property, where there is no intent to cause death or reckless indifference to safety of a person. Further, the offence of assaulting a member of crew of an aircraft (s. 206 - 14 years) is not applicable to drones, because it can only be committed by a person while on board the aircraft. Assaulting a drone operator may have similar consequences to assaulting a member of crew (in that it may cause them to lose control of an aircraft), yet it appears not to be the subject of a specific offence.

In the case of weaponised drones, some additional offences created since 2001 may be applicable, such as the intentional delivery of an explosive device (s72.3 of the Criminal Code (Cth) 1995)

Considerable differences exist among jurisdictions in such areas of law. In many jurisdictions, the technological features of drones may generate uncertainties and some of the provisions that appear to exist may be found not to be applicable. Particularly in the case of intentionally violent and harmful acts, however, considerable public concern is bound to arise where it is found that local laws fail to ensure severe criminal penalties, and adjustments to laws are likely to be implemented quickly.

(2) Laws Relating to Computing and Data Communications

Many jurisdictions have criminalised various acts relating to computing and data communications, and these may be as relevant to drones as to any other form of IT/ICT.

In Australia, for example, the following provisions of the Criminal Code 1995 (Cth) may be applicable where a person intentionally interferes with data- or control-streams:

- unauthorised impairment of electronic communication to or from a computer, in order to commit, or facilitate the commission of, a serious offence (s.477.1 - penalty as applicable to the serious offence)
- causing of any unauthorised modification of data held in a computer (s.477.2 - 10 years)
- unauthorised impairment of electronic communication to or from a computer (s.477.3 - 10 years)
- unauthorised access to, or modification of, data to which access is restricted by an access control system (s.478.1 - 2 years)

In addition, provisions of the Radiocommunications Act (Cth) criminalise `jamming' of signals, defined as unlicensed operation or even possession of a radiocommunications transmitter (ss.46-47 - 2 years).

Unauthorised interception of communication passing over a telecommunications system is prohibited by the Telecommunications (Interception and Access) Act 1979 (Cth) (TIAA) - even though its primary function is to authorise interceptions and access by government agencies (ss.7, 105 - 2 years). The TIAA also provides a very limited civil remedy under s.107A, contingent on the offence being prosecuted and a conviction gained. It is also an offence to access a stored communication, or facilitate access by another person, unless both sender and recipient know of the access - although their consent appears not to be required (s.108 - 2 years).

In the case of hijack of a drone's behaviour, possibly relevant offences under the Criminal Code include:

- possession of an interception device (s.474.4 - 5 years; and the onus is on the defendant to prosecute their innocence)

- tampering with, or interference with, a facility owned or operated by a carrier (s.474.6 - 1 year, or 2 years if the conduct results in hindering the normal operation of a carriage service)
- use of a telecommunications network with intention to commit a serious offence (s.474.14 - penalty as applicable to the serious offence)* use of a carriage service to menace, harass or cause offence (s.474.17 - 3 years)

The scope of these provisions appears to be far from settled. Moreover, there appears to be considerable reluctance by prosecuting authorities to use some of them, particularly the TIAA offences. Criminal laws generally do not assign liability, and hence have no role as a transference mechanism. It is unclear whether they will have a significant deterrent effect against casual, or reckless, or aggressive behaviour that is likely to result in drone incidents.

A careful assessment would be necessary in each particular jurisdiction in order to understand the extent to which laws proscribing interference with computers and communications are applicable to conduct involving drones (particularly the hijacking of control). Even where such laws exist, their scope is limited. They may proscribe various types of hijacking and hacking, but will not ensure safe manufacture and operation of drones more broadly.

4.4 Conclusions

General civil and criminal laws may apply to acts in relation to drones that threaten public safety. This may, in some circumstances, result in punishment or at least the credible threat of punishment, for drone manufacturers and operators who cause harm to people or property. In some cases, a party suffering harm may be able to achieve recompense.

The risk of liability or punishment is also capable of acting as a deterrent. However, the deterrent is too general and the uncertainties involved are too great if the goal is to gain compliance with particular safety and co-ordination norms, such as those associated with air safety. That can only be achieved through more specific regulatory arrangements. The following section considers the specific laws that relate to air safety, the extent to which they do and do not apply to drones, and the extent to which they appear likely to be effective.

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5. Regulatory Arrangements Directly Relating to Air Safety

A century of aviation has seen the emergence and continual refinement of a very substantial set of institutional structures and processes relating to the safety of piloted aircraft. This has resulted in remarkably low levels of accidents and loss of life, despite the inherent dangers, the technical complexity, and the high standards of education and training demanded of pilots and support and maintenance staff. To what extent does the positioning of the pilot outside the aircraft undermine existing regulatory arrangements?

This section considers in turn the four forms of regulation identified earlier: formal regulation, co-regulation, industry self-regulation and organisational self-regulation.

5.1 Formal Regulation - Air Safety Laws

Formal regulatory frameworks comprise statutes and delegated legislation, and in some countries common law provisions, accompanied by enforcement mechanisms including both civil litigation and actions by an empowered and resourced government agency. Because of the vital role of international conventions in regulating air safety, it is appropriate to commence the analysis with the international legal framework. Subsequent sections consider laws, and indications of emergent changes to laws, in Australia, the USA and Europe.

(1) International Law

The context for regulation within individual countries is set by the Convention on International Civil Aviation, also called the Chicago Convention. A UN organisation, the International Civil Aviation Organisation (ICAO), headquartered in Montreal, has the responsibility to "promote the safe and orderly development of international civil aviation throughout the world". It does this through publication of a large number of Standards and Recommended Practices (SARPs). Virtually all countries are signatories to the Convention, and operational air safety matters are subject to regulation within national statutory frameworks. Individual countries may apply Rules different from the SARPs, but if so then they are required to file those Rules with ICAO.

Aviation regulation has been primarily concerned with piloted civilian aircraft, above a given size and generally operating above a given height and in sectors adjacent to airports. The focus of ICAO has always been on aircraft that are likely to cross national borders, and hence some categories, such as government-owned aircraft and what are commonly termed 'model aircraft', have been regarded by ICAO as being largely outside its scope, and individual countries have been left to establish their own regulatory frameworks.

The longstanding approach to managing risk in congested airspace, and in particular in the vicinity of airports, is to subject all aircraft entering the space to the authority of an air traffic control regime (e.g. ASA 2013). The conventional model of air traffic control involves:

- a controller, comprising an individual or a team, with:
  - responsibility for a designated airspace
  - considerable authority over the pilots of aircraft within that airspace
  - reliable near-real-time data on all aircraft within that airspace
  - reliable communications with the pilots of all aircraft within that airspace
  - sufficient capacity to compute paths for all aircraft within the airspace that satisfy both the intentions of the pilots and safety standards
- at least one pilot per aircraft, who:
  - is on board the aircraft and has responsibility for it
  - complies with the controller's instructions (although deviations from instructions are permitted to the extent required to maintain safe operation of the aircraft)

Drones challenge these assumptions in several ways. Most importantly, pilots are not on board their aircraft, but rather remote from them. This greatly increases the dependence of the aircraft's behaviour on reliable communications of the pilots' commands across space, and in most circumstances it dilutes the pilot's appreciation of the aircraft's surroundings. Drones are commonly smaller than piloted aircraft that perform a similar function, and hence less readily visible to the naked and assisted eye, but also to radar, giving rise to the risk of reduced quality in the data available to air traffic controllers. The lower cost of a drone is likely to increase the number of aircraft seeking access to any given segment of airspace, leading to a greater likelihood of not only physical congestion but also electronic congestion - which in turn threatens data quality and risks information overload on both air traffic controllers and their supporting infrastructure.

The Chicago Convention leaves the regulation of pilotless aircraft specifically to national laws. In particular, it contains the following provision: "No aircraft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting State without special authorization by that State and in accordance with the terms of such authorization. Each contracting State undertakes to insure that the flight of such aircraft without a pilot in regions open to civil aircraft shall be so controlled as to obviate danger to civil aircraft" (Article 8). Further, terms such as `pilotless', `drone', `UAV' and `unmanned' are almost nowhere to be found in ICAO's extensive library of SARPs.

Anorther important regulatory element is a clear framework for assigning liability for harm arising from aircraft incidents. The Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface (commonly `the Rome Convention') entered into force in 1958. To the extent that it has been adopted, it provides an incentive for signatory countries to ensure that an effective process exists. However, as at late 2013, there were only 49 signatories compared with 191 signatories to the Chicago Convention, and among the omissions are Australia, the USA and almost the entire EU.

The lack of drone-specific rules at the international level is likely due to the limited civilian use of pilotless aircraft during the decades following ICAO's establishment. Although the first steps were taken as long ago as 2005 (ICAO 2006), little has occurred since. A key factor appears to be the slow speed of the organisation's (necessarily) cumbersome multilateral processes.

An indication of the scope of topics that need to be addressed in order to produce workable formal Standards for drones is provided in Peterson (2005, pp. 49-63). Rules for the operation of mini- and micro-drones would appear likely to need further specialisation, and nano-drones embody additional and somewhat different challenges. Further, discussions about regulatory frameworks are generally focussed on remotely-piloted drones. The expression used in Article 8 of the Convention on International Civil Aviation nominally requires that signatory countries require that fully autonomous devices be specifically authorised and be subject to specific controls (Article 8). The relevant terms used by ICAO (2011, p.x) are defined as follows:

- Autonomous aircraft. An unmanned aircraft that does not allow pilot intervention in the management of the flight.
- Autonomous operation. An operation during which a remotely-piloted aircraft is operating without pilot intervention in the management of the flight.

ICAO (2011) expressly states that "Fully autonomous aircraft operations are not being considered in [its current] effort [regarding the regulatory framework for UAVs]" (p.3, emphasis added). In short, ICAO has not yet even commenced consideration of the adaptations necessary to ensure public safety against autonomous drones.

ICAO's study group appears not to have made any documents public beyond a circular (ICAO 2011), with a formal document not anticipated before 2014. The circular included a set of terms and associated definitions (p.x).

ICAO (2012) amended the International Standards on Rules of the Air (Annex 2 to the Convention) in order to create the following obligations on member-states. The obligations are not yet current, however, because the specific Standards are yet to be prepared:

- 1.1 A remotely piloted aircraft system (RPAS) engaged in international air navigation shall not be operated without appropriate authorisation from the State from which the take-off of the remotely piloted aircraft (RPA) is made.
- 1.7 RPAS shall meet the performance and equipment carriage requirements for the specific airspace in which the flight is to operate.
- 2.1 An RPAS shall be approved ...
- 2.2 An operator shall have an RPAS operator certificate ...
- 2.3 Remote pilots shall be licensed ...

Some clues as to the direction in which thinking is proceeding may be gained from the definitions in ICAO's 2012 document, which are variously a little different from and additional to those in ICAO (2011). However, nothing in ICAO (2011, 2012) appears to lay the groundwork for differential regulatory arrangements for large drones and for the various categories of small drones, nor for different obligations relating to commercial uses and to personal uses. It may be that ICAO treats `other-than-commercial use', `recreational use' and 'model aircraft' as being co-terminous, and entirely out-of-scope: "Model aircraft, generally recognized as intended for recreational purposes only, fall outside the provisions of the Chicago Convention, being exclusively the subject of relevant national regulations, if any" (ICAO 2011, p.3). A search of the Convention discloses no occurrence of the terms `recreational' and `model'. The scope of the Convention, and of ICAO, is `civil aircraft', i.e. excluding `state aircraft' which includes those of `military, customs and police services' (Article 3). It is therefore unclear on what basis ICAO claims that personal uses of drones lie outside its scope.

Apparently because the ICAO arrangements have been piecemeal and very slow, an additional 'harmonisation group' was formed in December 2012, called Joint Authorities for Rulemaking on Unmanned Systems (JARUS). It comprises primarily the national agencies from within and beyond Europe, and is chaired by The Netherlands. The first official publication emerged in late 2013 (JARUS 2013). This is a Certification Specification for rotorcraft up to 750kg, using Visual Line Of Sight Operations and excluding all human transport, flight into known icing conditions, and aerobatics. Challenges arise in interpreting the significance of the document, not least because neither it nor the few other available documents provide any reconciliation against aircraft Standards (such as those for small helicopters). It lacks a lower weight-threshold, and hence it appears to be intended to be applicable to mini-, micro- and nano-drones.

The international framework for drone regulation is currently incomplete and immature. The following sections consider the current and emergent state of drone regulation in several parts of the world.

(2) Australia

Australia offers several advantages as the first jurisdiction to be considered. It is the authors' home jurisdiction, it has been and remains a very active and advanced user of aviation technologies, its primary airspace is a long way from its nearest neighbours (which makes the operations and the analysis much simpler than is the case in Europe), it has a relatively small number of major airports and only moderately congested airspace (making it much simpler to assess than the USA), and it was an early mover in drone regulation. The approach adopted is thus to first describe the important aspects of air safety laws in Australia, and to then provide an outline of the regimes in the USA and Europe.

Australia's air safety commitments under the UN Convention are implemented by means of the Air Navigation Act 1920 (Cth) and Air Navigation Regulations 1947 (Cth). The primary government agency responsible for regulatory arrangements associated with air safety is the Civil Aviation Safety Authority (CASA). In order to facilitate the management of airspace, a distinction is made between controlled and uncontrolled airspace. Entry to controlled airspace by any aircraft or person requires clearance from the relevant air traffic controller. Three categories of controlled airspace are distinguished (CASA 2013b):

- terminal airspace, surrounding a major airport, which includes space immediately above it, and an inverse cone expanding 30 to 50 nautical miles (55 - 90 km) away from the airport
- en-route airspace, which refers to space reserved for flight-paths
- other restricted airspace, e.g. around military installations and airshows

The use of 'model aircraft', i.e. small, recreational devices, is subject to regulation in the form of 11 pages of statute and 16 pages of Regulations, referred to as CASR-101-3 (CASA 1998b). This applies to drones between 100gm and 150kg that are "flown for sport or recreational purposes". CASR 101-3 is a greatly scaled-down requirement in comparison with that for pilot-on-board aircraft. There are no requirements for model aircraft registration, pilot licensing or model aircraft airworthiness certification. Aircraft below 25kg must be flown in Visual Line of Sight (VLOS) mode, which precludes First Person View (FPV) operations, unless at an approved site. For `giant model aircraft', above 25kg, the rules of the Model Aeronautical Association of Australia (MAAA) apply (7.3.1, p.4). These greatly limit where flights are permitted and require aircraft inspection; and those above 50kg must be inspected by CASA rather than MAAA.

The use of any drone for a purpose other than sport or recreation is subject to the more substantial requirements of CASR Regulation 101-1 (CASA 1998a). CASA is understood to have been the first national agency to issue operational regulations for drones, which have been in force since 2002. An overview is provided in Peterson (2005, pp. 81-87). This provides that, "[i]n general, when operating in controlled airspace, UAVs should be operated in accordance with the rules governing the flights of manned aircraft" (5.1.1, p.2). It goes on to say that "[p]rovided that a small UAV is operated not above 400 ft AGL [undefined in the document, but meaning Above Ground Level] and remains clear of designated airspace, aerodromes and populous areas, there are no restrictions imposed upon the operation of a small UAV [and it] will not require approval" (7.1.1 on p.9 and 12.1.1, p.16). On the other hand, the same paragraph states that "an Operator Certificate ... is required for all commercial UAV operations" (12.1.1, p.17, emphasis added).

The same device may therefore be subject to different regulatory frameworks depending on the use to which it is put. The categories of UAV use that bring a device and its operator under CASR 101-1 rather than 101-3 are expressed in various, inconsistent ways in various CASA documents. In CASA (2013e), the term `flown for air work' is used, with `commercial use' as a sub-set rather than as the definition. That definition appears, however, to lack force of law because it is absent from CASR 101-1. CASR 101-1 and CASR 101-3 both declare devices `flown for sport or recreational purposes' to not be subject to 101-1, but to instead be within the scope of 101-3. It might be inferred that `commercial' and `sport and recreational' are disjunct concepts, and that they together define the universe of uses; but, particularly in view of CASA's use of the term `air work', that inference may well be wrong.

CASR 101-1 leaves important elements subject to unreferenced authorities or uncertain interpretations, giving rise to the suspicion that prosecutions for a range of apparent breaches of the Regulations, if any were ever attempted, may well fail. This is because the following thresholds are mentioned in CASR 101-3 applying to model aircraft, but do not appear in CASR 101-1 applying to drones:

- "clear of ... aerodromes" is interpreted as "three nautical miles"
- "clear of ... populous areas" is interpreted as "30 meters from people", other than those directly involved in the operation
- the notion of 'small UAV' is addressed by a speech in which it is stated to mean less than "150 kg (100 kg for rotorcraft)", a threshold that it acknowledges is arbitrary (CASA 2013a). The 150kg threshold is expressed in CASR 101-3 but not 101-1, and the 100kg alternative for rotorcraft is expressed in neither Regulation

It is possible that some aspects of the existing regulatory regime may change in the near future. In order to adapt CASA 101-1 to reflect subsequent developments, a review has been in train since July 2011. Among other things, "CASA is now looking at introducing a weight limit to make it less onerous, but still safe, for commercial operators to use small remotely piloted aircraft" (CASA 2013a). CASA has gone as far as signalling that it simply cannot ensure public safety: "We have to address the current reality. There is no point in CASA writing regulations that can't be enforced. Therefore, CASA is in the process of writing some rules it can control" (CASA 2013d).

During 2013, CASA conducted consultations with the industry - although apparently not with representatives of the public - with a view to greatly reducing the safety requirements, by segmenting drones into four weight-bands. The regulator was reported in Corcoran (2013) as having determined that 2-7kg drones will require a risk assessment, and be subject to a half-dozen-page rule book. On the other hand, 2kg drones were compared with 160gm cricket-balls, and regarded as not life-threatening, but only good for a headache or a bruise, and were therefore not worth regulating. This seems to be a remarkable comparison considering that the kinetic energy of such a drone is 14-50 times that of a cricket-ball moving at the same velocity, cricket balls have a narrow and predictable trajectory whereas drones do not, and cricket balls have no potentially dangerous moving parts.

Autonomous drones are also largely ignored by the Australian regulatory regime. Subject to some conditions, `autonomous operation' is permitted: "Nothing contained in this document is meant to preclude operation of a UAV in an `autonomous' or programmed flight mode, provided that UAV performance and designated ATC communication circuits are continuously monitored by the UAV operating crew, and that the UAV system and crew are capable of immediately taking active control of the UAV" (CASA 1998a, 5.2.2, p.2). No further, more specific requirements were located.

CASA is concerned with safeguards that have primary, i.e. preventative and deterrent, influences on aviation safety. Back-end safeguards are also needed, to enable investigation, and apportionment of blame to the guilty and of liability to those held to be financially responsible for harm arising. Investigations into aviation incidents are performed by an agency separate from CASA, the Australian Transport Safety Bureau (ATSB). However, the objectives of ATSB investigations are expressly limited to ensuring improvements in transport safety, and are "not for the purposes of apportioning blame or liability" (emphasis added). As at the end of 2013, ATSB had yet to publish a single accident report involving a drone (ATSB 2013), although one incident was under (slow) investigation. This is despite incidents of significance being reported to it, including a drone in controlled airspace over a regional airport in October 2012, a 2kg fixed-wing drone destroyed bv a crash following birdstrike in January 2013, a seriously damaged drone from a crash following loss of communications in June 2013, and a close encounter with an aircraft over a country airport on 12 or 14 September 2013, categorised as a `Serious Incident' (ATSB 2014), but for which no report existed 5-1/2 months later.

Concerns arise from time to time about inadequate standards, inadequate responses to incidents, inadequate applications of sanctions, and excessive delays in imposing them - which are indicators of at least some degree of capture of the regulator by the industry it is meant to regulate. Criticisms of CASA and ATSB have even been levelled by a sometime Chair of CASA (Smith 2005). Examples of CASA's extremely casual approach to drone incidents are documented in CASA (2013d) and LL (2013). In the second case, the `regulator' claimed to be still considering whether it should take any action 5 months after a well-publicised incident occurred, and 4-1/2 months after the miscreant, a `roadie' for an overseas entertainment artist, was known to have left the country.

A ustralia is not a signatory to the Rome Convention on Damage Caused by Foreign Aircraft. However, liability for "injury, loss, damage or destruction" suffered as a result of any form of impact arising from the operation of a civilian aircraft is determined under the Damage by Aircraft Act 1999 (Cth). Under s.10(2), liability is assigned to one or more of the operator, the owner and the current lessee of the aircraft. Recovery can be achieved "without proof of intention, negligence or other cause of action, as if the injury, loss, damage or destruction had been caused by the wilful act, negligence or default of the defendant or defendants" (s.11). Under s.4, `aircraft' means "any machine or craft that can derive support in the atmosphere from the reactions of the air, other than the reactions of the air against the earth's surface [which presumably excludes hovercraft and perhaps rockets from the provisions] ... but does not include model aircraft" (emphasis added). Liability for the harm arising from impacts of drones therefore depends on interpretation of whether each particular drone is a `model aircraft' for the purposes of that Act. The effect of that law is that many drone incidents will give rise to strict liability for any harm arising. For motor vehicles, third-party insurance has been compulsory for many decades, e.g. since 1930 in the U.K. and 1939 in Germany. The conditions appear to be rapidly emerging under which compulsory insurance needs to be imposed on the operators of drones, whether they are used for commercial purposes or otherwise.

This brief review has identified the considerable complexity of the laws regulating the flight of drones in Australia. A search of the CASA web-site failed to locate straightforward guidance in relation to the particular Regulations that are applicable under various circumstances. Table 3 was accordingly inferred from the various CASA documents. It is expressed in the conventional form of a decision table. Each column defines which regime applies to a particular set of conditions. In the upper half, a tick indicates a condition that must apply, `x' indicates a condition that must not apply, and `-` indicates a condition that is not relevant in those specific circumstances. In the lower half, the applicable regulatory features are identified with a tick.

Table 3: Regulatory Frameworks Applying to Drones in Australia

DETERMINATIVE FACTORS									
Controlled Airspace	√	–	x	x	x	x	x	x	x
> 150kg (Fixed-Wing / 100kg for Rotorcraft?)	–	√	x	x	x	x	x	x	x
Commercial Use	–	–	√	x	x	x	x	x	x
< 150kg (Fixed-Wing / 100kg for Rotorcraft?)	–	x	√	√	√	√	√	√	√
< 150kg but > 50kg	–	x	–	√	x	x	x	x	x
< 50kg but > 25 kg	–	x	–	x	√	x	x	x	x
< 25kg	–	x	–	x	x	√	√	√	√
< 7kg but > 2 kg	–	x	–	x	x	x	√	x	x
< 2kg but > 0.1kg	–	x	–	x	x	x	x	√	x
< 0.1kg	–	x	–	x	x	x	x	x	√
APPLICABLE REGULATORY REGIME									
Full Regulatory Framework (CASR)	√	√	–	–	–	–	–	–	–
Limited Regulatory Framework (CASR 101-1)	–	–	√	–	–	–	–	–	–
Model Aircraft Framework (CASR-101-3)	–	–	–	√	√	√	√	√	–
+ MAAA Rules	–	–	–	√	√	–	–	–	–

+ CASA Inspection	√	√	√	√	–	–	–	–	–
+ MAAA Inspection	–	–	–	–	√	–	–	–	–
(Emergent light regulatory scheme)	–	–	–	–	–	–	(√)	–	–
(Emergent even-lighter regulatory scheme)	–	–	–	–	–		–	(√)	–
Damage by Aircraft Act	√	√	√	–	–	–	–	–	–

The complexity alone raises doubts about both the effectiveness of the current regulatory framework's transference and deterrent effects on irresponsible behaviour by the operators of small drones. Given the almost complete absence of enforcement in relation to the operation of mini- and micro-drones, and CASA's public statements exonerating itself of responsibility, regulatory failure is clearly evident.

(3) USA

The USA's air safety regulatory agency is the Federal Aviation Administration (FAA). It publishes Federal Aviation Regulations (FARs), building on ICAO's SARPs. The definitions used in the regulatory instruments are such that they are in general as applicable to drones as to any other kind of aircraft. An overview of the rules as they existed at that time is in Peterson (2005, pp. 64-81).

In relation to drones specifically, FAA published guidelines (FAA 2005), a policy document (FAA 2007) and a Fact Sheet (FAA 2010). The current position is confusing, and highly restrictive: "UAS are typically given access to airspace through the issuance of Certificates of Waiver or Authorization (COA) to public operators and special airworthiness certificates in the experimental category for civil applicants" (FAA 2013b, p.5, emphasis added). More specifically:

- public agencies must apply for a Certificate of Authorization (COA), even for the operation of small drones below the 400 feet ceiling. FAA states that it interprets 'public agency' very broadly. Among other activities, this has held back public universities seeking to use drones in their courses, e.g. for journalism (O'Neil 2013)
- an Order exists relating to a 'special airworthiness certificate in the experimental category' (SAC-EC), but its scope of applicability is unclear (FAA 2008). On p.3-1 is found the statement that "In no case may any UAS be operated as civil unless there is an appropriate and valid airworthiness certificate issued for that UAS". That appears to be in conflict with the issue of COAs to public agencies
- the use of drones in autonomous mode, and even of fully autonomous drones, may be licensed on a case-by-case basis, perhaps restricted to line-of-sight operations (Goth 2009)
- there is an ancient, vague, 13-line 'Advisory Circular' for model aircraft, whose scope of applicability is anything but clear and which has no force of law (FAA 1981)

The widely-held interpretation is that FAA can preclude the use of drones of any size, by anyone, for any purpose other than recreation, without explicit FAA approval; that it has exercised that power; and that FAA approval is very challenging to achieve (Niles 2013). What was described as "the first FAA-approved commercial flights by an unmanned aircraft" was achieved only in September 2013, and the authorisation only applied in the Arctic, and during the short northern summer (FAA 2013a). As late as the end of 2013, FAA could state only that "Through August 2012, the FAA had issued ... special airworthiness certificates ... to 22 different models of [UAS]" (FAA 2013b, p.22).

The counts of drone-models, and of organisations that want to use them, have grown quickly. There is a strong likelihood that considerable benefits can be gained from some applications of drones, and in any case the USA is characterised by a widespread dislike of government intervention. A great deal of pressure has accordingly been brought to bear by the business sector, seeking a loosening of the constraints. This creates considerable risk that drones may become subject to inadequate controls, resulting in unreasonable threats to public safety. It is therefore vital that a framework be quickly established that balances competing interests and embodies suitable controls.

The FAA Air Transportation Modernization and Safety Improvement Act, enacted in February 2012, was intended to force the organisation's hand, by mandating that the FAA:

- begin allowing law enforcement use of small drones (i.e. under 4.4 pounds = 2kg) by mid-2012
- establish more permissive drone regulations by 30 September 2015, including allowing more widespread use of drones by private parties

The first mandate appears to have been complied with merely by loosening up the processes relating to the issue of COAs. More than halfway through the 43 months originally allowed for compliance with the second mandate, very little had been achieved. In September 2013, the US Secretary for Transportation submitted a 'UAS Comprehensive Plan' to Congress (ST 2013), and in November 2013, FAA published what it called a 'UAS Roadmap' (FAA 2013b). Unfortunately, the road continues to be paved with mud. The Roadmap is merely aspirational. It talks of policy development, of changes to Regulations, and of the development of Standards, in the future tense. Almost 2 years into what Congress intended as a 3-1/2-year program, what is presented is a "five-year roadmap" (p.6). Rather than being definitive, the document is envisaged as an annual publication. It offers no schedule for changes to Regulations and publication of Standards, but provides only a 'Conceptual Timeline' (p.26).

FAA summarises the challenge as follows: "While UAS share many of the same design considerations as manned aircraft, such as structural integrity and performance, most unmanned aircraft and control stations have not been designed to comply with existing civil airworthiness or operational standards ... [There is a need] to move away from the existing experimental or expendable design philosophy, toward a design philosophy more consistent with reliable and safe civilian operation over populated areas and in areas of manned aircraft operation" (FAA 2013b, pp.23, 25). "Current UAS ... do not fly traditional trajectory-based flight paths and require non-traditional handling in emergency situations. UAS cannot comply with [Air Traffic Control] visual separation clearances and cannot execute published instrument approach procedures. ... For the near-term, it is expected that UAS will require segregation from mainstream air traffic" (p.27).

The scale of the effort needed to establish Regulations and Standards is indicated by Figure 3 in FAA (2013b, p.15), which identifies 39 categories of technical documentation under the headings of Pilot & Crew, Control Station, Data Link and Unmanned Aircraft; and Figure 4 (p.17), which adds 18 categories relating to Air Traffic Control, under the headings of Contoller (sic), Operations and Safety. But, even in its Technical Appendix on pp. 50-64, the document fails to demonstrate that any of FAA, the industry association RTCA, or ICAO, has a structured and resourced program in place to deliver against the requirements.

Of particular significance is the vagueness of the FAA's position in relation to Small UAS, which are defined as "unmanned aircraft weighing less than 55 pounds [25kg]" (p.48). In particular, "Except for some special cases, such as small UAS (sUAS) with very limited operational range, all UAS will require design and airworthiness certification to fly civil operations in the NAS" (p.11). No plan or timetable has been published to achieve compliance with the Congressional deadline of 30 September 2015, even in respect of small drones. A series of clarifications published by FAA as this paper was finalised still provided no date-commitment, merely referring to "later this year" (FAA 2014).

A concrete step occurred at the very end of 2013, when FAA announced six research and test sites to address the agency's "research goals of System Safety & Data Gathering, Aircraft Certification, Command & Control Link Issues, Control Station Layout & Certification, Ground & Airborne Sense & Avoid, and Environmental Impacts", across a range of climatic zones and geographies (FAA 2013c). However, the announcement contained nothing about deliverables, timeline or consultative processes.

A further issue is that public interest advocacy organisations see as inadequate the range of factors that FAA considers when determining Regulations. "The FAA is required to take safety into account when promulgating regulations, and, in some limited circumstances, also must consider the public interest" (EPIC 2012). ACLU (2011) has called for safeguards in the areas of public participation in policy formation, limits on purposes, abuse prevention, accountability for abuse, and preclusion of weapons. An indication of how little attention FAA is paying to the concerns of the broader community is that the Roadmap document was addressed to "the Aviation Community".

It appears that it will be some time before a coherent and workable regulatory framework is in place and understood by the parties subject to the regulation and the intended beneficiaries. In the meantime, the likelihood of unauthorised use and of harmful incidents is rapidly increasing. Public concern in the USA has manifested itself in a wide variety of Bills being tabled in 43 State legislatures, with legislation enacted in 9 States to the end of 2013 (ACLU 2014. See also Dalamagkidis et al. 2012 and Niles 2013).

Observation of a parallel development is instructive. In June 2011, Nevada became the first US State to pass a law regulating driverless robotic cars The definition of an autonomous vehicle is "a motor vehicle that uses artificial intelligence, sensors and global positioning system coordinates to drive itself without the active intervention of a human operator". This is awkwardly over-specific in several ways:

- GPS is not a necessary feature of an autonomous vehicle
- AI, as defined ("the use of computers and related equipment to enable a machine to duplicate or mimic the behavior of human beings"), is not necessarily a feature either, because the behaviour may be defined other than by reference to human behaviour
- it could be read as excluding from the law's purview vehicles whose autonomous capabilities can be overridden by the driver

The notion of entirely technology-neutral regulation is a counsel of perfection - an aspiration, but not one that can be reliably achieved. On the other hand, strongly technology-specific regulation needs to be avoided. Such approaches are highly vulnerable to technological change, and hence fail to achieve their aims.

(4) Europe

The European Aviation Safety Agency (EASA) has responsibility for civil aviation safety within the European Union (EU). Recognition of the need to address drones dates to at least as early as 2002, and a joint task force report was published two years later (JAA 2004). The relevant Regulation is No 216/2008, as amended. This applies to drones over 150 kg, other than those operated by agencies of national governments. For both government-operated drones and those lighter than the arbitrary threshold of 150kg, regulation is left to each individual country, although some drones may be subject to EC Directive 2009/48/EC of 18 June 2009, on the safety of toys.

EASA has issued a Notice of Proposed Amendment, numbered NPA 2012-10 (EASA 2012), to apply the principles contained in ICAO (2012) to RPAS above 150 kg and used for commercial air transport - CAT, e.g. freight - or for specialised operations - SPO, e.g. aerial photography (EASA 2012). However , a document published by a large group of industry stakeholders convened by the EC criticises the current arrangements, and makes it appear that the EU is only at the 'roadmap' stage for adaptation of the existing framework for recent developments, with a target of 2016 for an adapted framework to be in place (EC 2013). This document envisages:

- a coherent suite of rules relating to five different categories of operations distinguished by the availability of line-of-sight operation and altitude, to be introduced c. 2016 (p.13)
- transfer of the regulatory responsibility for drones less than 150kg to EASA from c. 2016 (p.7), although possibly leaving drones of less than 25kg as a national responsibility (p.15)

On the other hand, European officials have recently been accused of being in far too cosy a relationship with the drone industry: "the European Commission has effectively funded the drone industry to lobby the EU for subsidies, market opportunities and a favourable regulatory environment" (Hayes et al. 2014, p.9).

EC Regulation 785/2004 (EC 2004) stipulates requirements relating to accident insurance for aircraft weighing more than 20kg. This appears to apply to drones.

An examination of the laws of each EU country in relation to the smaller categories of drones and all government drones is well beyond the scope of this paper. For an overview of the interaction between the then provisions of the EU and those of one particular country, the UK, see Peterson (2005, pp. 89-95). The current UK provisions (CAA 2012a, 2012b) bear comparison with those in the USA, but distinguish between:

- UAS (>150kg) - which are subject to a regulatory regime
- Light UAS (20-150kg) - to which some limited airworthiness requirements apply

- Small Unmanned Aircraft (<20kg) - to which a very limited set of conditions apply (see CAA 2012a at 253)

In relation to model aircraft, a separate, shorter and simpler publication applies in the UK (CAA 2013). A model aircraft is distinguished from a drone on the basis of its use solely for sporting or recreational purposes. Large model aircraft (over 20kg) are subject to a licensing requirement (referred to as an `exemption'). Above 150kg, model aircraft are subject to the same regulations as piloted aircraft.

As in Australia and the USA, European countries appear not be adapting existing aviation rules sufficiently rapidly to cater for the drone explosion, particularly in relation to the various categories of small drone.

(5) Conclusions

In relation to piloted aircraft, at least in each of the USA, Europe and Australia, a regulatory agency exists, has powers, expertise, resources, and commitment to the monitoring of relevant conduct, and does, at least on occasions, impose sanctions, including revocation of licences. These regimes generally extend to large drones, and to some limited extent at least to drones operating in controlled airspace.

On the other hand, smaller categories of drones are subject to very limited regulatory frameworks. It is therefore important to consider the extent to which the other three regulatory forms address the gaps.

5.2 Co-Regulation

Co-regulation refers to a regulatory model in which industry has significant input to a set of requirements, and perhaps even prepares them, but does so within a statutory context that makes the requirements enforceable (Hepburn 2006). A useful term to distinguish such instruments from mere industry codes is 'Statutory Codes'. Where the requirements are articulated into fine particulars, as is the case with conventional aviation, `Statutory Standards' is a useful term for the detailed specifications.

This approach has theoretical advantages, which may be real advantages if the conditions described in Table 2 are fulfilled (Clarke 1999). It can provide a formal regulatory framework, led by a sufficiently powerful and well-resourced agency, to ensure that public needs are satisfied. In addition, it can ensure that the Codes and Standards are meaningful to the parties subject to that regulator, which comprise industry players that are well-informed about the technological landscape in which the regulation will operate, and that have considerable influence over the contents of the documents.

On the other hand, the process and product are potentially compromised, and even seriously so, to the extent that power is exercised over the regulator by the parties nominally subject to them. Some balance between the two extremes can in principle be achieved where stakeholders other than the industry are also involved, and the relevant parliament and government credibly wield the power to abandon the co-regulatory approach and impose formal regulation. Those conditions cannot be satisfied unless other stakeholders, and particularly the public, are granted a seat at the negotiating table, and both empowered and resourced. In practice, it is common for the interests of industry players to dominate the process and the outcomes.

In the USA, a substantial standards development and maintenance process is run through the Radio Technical Commission for Aeronautics (RTCA). The organisation's web-site describes RTCA as a "Public-Private Partnership venue for developing consensus", and says that it is "utilized as a Federal advisory committe e", and that it "works in response to requests from the Federal Aviation Administration (FAA) to develop comprehensive, industry-vetted and endorsed recommendations for the Federal government". RTCA's effectiveness in relation to the operation of drones appears to have been to date far lower than its effectiveness in aviation more generally. A commercial web-site at http://www.uavm.com/ suggests that RTCA had a number of standards development processes in train for aspects of (large) UAVs - subsequently re-named UAS - and their operation. These processes appear to have been instigated in about 2004, with expectations of progressive implementation from 2007-2013.

On the other hand, the organisation's publications catalogue (RTCA 2013) contains no formal Standards, and only a small number of educative and `framework' documents. Moreover, it appears that the initiative stalled, because a new Committee was formed in May 2013 (SC-228 Minimum Operational Performance Standards [MOPS] for Unmanned Aircraft Systems). Initial White Papers were scheduled for December 2013 (but no publications had appeared by February 2014) and July 2015, and hence progress with MOPS appears to be still quite some years away. Further, it is unclear to what extent this initiative is coordinated with international activities, and it does not appear that the scope extends to mini- and micro-drones.

Hence, even in the USA, where the industry is at its most dynamic, the development of Codes and Standards appears to have commenced late and/or to have commenced early but failed; and, even in the case of large drones, is years away from delivering the necessary Standards. There is evidence of close cooperation between regulators and regulatees, but the process appears to fail a considerable number of the criteria identified in Table 2 for an effective regulatory regime. In particular, there may be a lack of transparency and participation by key stakeholders, especially beneficiaries, and as a result the process may fail to satisfy the need for reflection of stakeholder Interests.

Although Europe is often perceived to have inclusive processes, neither EASA (2012) nor EC (2013) show much evidence of engagement with stakeholders outside the industry, and Hayes et al. (2014) is extremely critical of the European Commission's behaviour.

It would be quite feasible, and even desirable, for a co-regulatory approach to be adopted to the management of public safety aspects of drones, resulting in a regime satisfactory to all parties. This might be seen as being particularly appropriate to the use of micro-drones by individuals for non-commercial purposes. However, the emergence of such a regime is not imminent, and the power of industry associations and military interests may preclude it.

5.3 Industry Self-Regulation

Industry self-regulatory mechanisms arise where collectives of corporations impose constraints on all corporations in an industry, or at least on those corporations that are members. The stimulus for industry self-regulation is generally that the key players in the industry anticipate events and opinions that would limit their ability to do business, and that a collective can conceive and implement proactive, or at the very least reactive, measures that are seen to, and perhaps even that actually do, address the perceived problems.

Two indicators can be used to check whether actions by corporate collectives represent an effective constraint on excesses. Firstly, it might be expected that industry associations would be in evidence, and that those organisations would have clear Codes, would require members to commit to them, and would offer some kind of guarantee of the credibility of the Codes and their impact.

In the case of drones, there appears to have been insufficient action within both the general aviation industry and the drone industry itself. A primary organisation of the relevant kind is the Association for Unmanned Vehicle Systems International (AUVSI). One reference traces the organisation to 1972, when it was formed as the [US] National Association of Remotely Piloted Vehicles (NARPV). The Association claims membership of "more than 2,700 organizations from over 60 countries", and many chapters in the US plus Israel and the UK. It has published a Code of Conduct (AUVSI 2012). However, the Code is brief, and a statement of aspiration, with no evidence that it even becomes an undertaking by member-corporations, let alone creates any obligations that are subject to an enforcement framework. The AUVSI Code has been criticised as being neither motivated by high ideals nor even created as a strategic measure: in mid-2012, the US Congress buckled to industry lobbying and instructed the US aviation regulator to open up US airspace to drones. This stirred public sentiment, and "faced with the backlash, ... AUVSI ... tried to stem the bleeding with a classic move from the bad-press playbook ... it issued an industry `code of conduct'" (Singer & Lin 2012).

Law enforcement agencies are a special user-segment in some respects, but a user segment nonetheless. The International Association of Chiefs of Police (IACP) has published a set of `Recommended Guidelines' for drone operations (IACP 2012). But the Guidelines are preliminary, unenforceable, infinitely malleable, and appear not to have benefited from any consultation with stakeholders.

In Australia, two industry associations are endeavouring to influence industry practices, one dominated by drone suppliers, the Australian Association for Unmanned Systems (AAUS), and the other whose members are primarily drone operators, the Australian Certified UAV Operators (ACUO). There was no evidence of meaningful progress as at the end of 2013.

A second indicator of effective industry self-regulation would be the existence of industry Standards, prepared by, or with considerable input from, key players in the industry, and published by recognised standards association and ultimately the International Standards Organisation (ISO). An example in the robotics arena is the industrial robot safety standard ANSI/RIA R15.06-1999.

In common with other mature industries, aviation as a whole has a vast array of industry Standards. For example, the web-site of the International Civil Aviation Organisation (ICAO) provides access to several hundred Standards documents that it has originated or adopted, but none relate to drones.

The USA has long claimed leadership in the aviation industry. The American Society for Testing and Materials (ASTM) has developed and published a range of industry Standards relating to drone manufacture, through its Committee F38 on Unmanned Aircraft Systems (UAS). These can be located by searching for <UAS> on the organisation's web-site. We were unable to locate a catalogue showing dates of publication, but see ASTM (2013). Drone operations, on the other hand, do not appear to be the subject of industry standards. This impression is reinforced by mentions of Standards in industry documents that suggest that drone industry players do not intend to develop operational standards as a form of industry self-regulation, but rather are waiting for governments to initiate such processes.

The model aircraft industry, enjoying as it does very light-handed regulation, might be expected to have invested in Standards in order to keep parliaments and regulatory agencies at bay. On the contrary, however, it appears to operate without industry Standards. One of the few relevant sources found is a remarkably brief (115-word) document that makes a statement about `Model Aircraft Operating Standards' rather than referring to any industry standards, or declaring any requirements (FAA 1981). Even when confronted by the mandate provided by Congress to the FAA in relation to drones, the [US] Academic of Model Aeronatics has merely issued a one-page `Model Aircraft Safety Code', to take effect in 2014 (AMA 2013).

The Fédération Aéronautique Internationale (FAI), also called the International Air Sports Federation, formed in 1905, has a very substantial library of documents making up its `Sporting Code'. The word `safety' appears very sparingly, however, and FAI appears not to have prepared, facilitated, promulgated, or recommended any safety-related Standards. Section 12 of the Code is entitled `Unmanned Aerial Vehicles' (FAI 2001), but it has no provisions relating to safety.

In any case, there is a longstanding inadequacy in relation to the development of industry Standards. Stakeholder representation in standards-setting processes is seriously skewed, and consumers are largely excluded. Clarke (2010) proposed a measure that was intended to force adaptation of these processes. This involves civil society rejecting industry-dictated Standards, and instead establishing and projecting their own Standards. Given the current vacuum, an opportunity exists to apply this approach in the drones area. However, the gaps in both expertise and resources make it unlikely that the opportunity will be taken up.

A further possibility is that collectives of individual professionals could impose constraints on their members, and thereby contribute to controls relating to drone risks. Bodies of professionals, particularly of engineers, might have some regulatory impact, through the educative effect of their Codes of Ethics on their members and even non-members, their 'moral suasion', and application of the Codes in disciplinary proceedings and in expert evidence in court cases.

A range of aircraft professions have published Codes, some including commitments by their members relevant to safety. See, for example, ISASI (1983), ALPA (2001) and PAMA (2012). Where a category of professionals controls a specialisation, and hence has a degree of market power, some of these Codes may represent at least a theoretical and occasionally even a real check on abuses in the aviation sector. A few may have some limited application in relation to the operation of drones.

As discussed at length in the second paper in this series, drones are a cross-over point between the aviation, computing, data communications and robotics industries. A further professional association of relevance is therefore the Institute of Electrical and Electronics Engineers (IEEE). However, IEEE's Code of Ethics and associated documents contain nothing related directly even to robotics let alone drones. An IEEE Technical Committee on Roboethics has existed since 2004, but with no meaningful outcomes apparent. A full 70 years after Asimov's celebrated Laws of Robotics were coined (Clarke 1993), an instrumentalist literature on the regulation of robots is only slowly emerging (e.g. Stuurman & Wijnands 2001, Anderson & Anderson 2012, Richards & Smart 2013).

Proposals about the responsibilities of IT professionals have fallen on deaf ears, e.g. Clarke (1988) re computing generally, Clarke (1993) re robotics generally, and Clarke (2011) re cyborgism. The authors have seen nothing to suggest that a similar call in 2014, in relation to drones, would enjoy any greater success than the earlier calls. The professional associations simply are not listening. In any case, the impact of such Codes on the behaviour of corporations is marginal, and disciplinary proceedings against professional members for performing acts for corporations or government agencies that breach a professional Code are almost unheard of.

With the exception of some ATSM Standards relating to manufacture, there appear to be very few relevant industry Codes, industry Standards or professional Codes relevant to drones, and such as exist were not the result of consultative processes that engaged all relevant stakeholders, and appear to have no impact anyway. So there is no evidence of any material regulatory effect on drone design and deployment arising from corporate collectives, nor from professional collectives. Hence there appears to be no industry self-regulatory mechanism that could make good the deficiencies in formal and co-regulatory mechanisms for ensuring public safety in the deployment of civilian drones.

5.4 Organisational Self-Regulation

There are several drivers for organisations to impose constraints on their own actions. Some may regard the notions of business ethics and Corporate Social Responsibility as something more than mere window-dressing. Others may recognise the strategic importance of allaying concerns in government, among stakeholders, and among the general public, in order to avoid harm to reputation, impediments to adoption, and the imposition of regulatory measures. Many more may be impacted by such concerns, and react tactically in a belated endeavour to address them.

A scan of the sites of major players in the drone industry finds little to suggest that self-control is a major inhibitor on excesses. For example, the French Parrot Drone is claimed by the company to represent the largest volume of consumer-level micro-drones. The company's web-site contains no cautionary comments and plenty of incautious marketing expressions ("Trying your most daring tricks won't even challenge this cutting edge design", although that is somewhat qualified by "fully reparable"; and "Fly high. Fly fast. Far away from the ground"), and a company representative has testified to the Australian Parliament that its packaging includes disclaimers, but no user guidance in relation to either safety or legal constraints. The substantial web-site of an upper-end hobbyist product, the Chinese DJI Phantom 2 Vision, contains the word `reliable', but otherwise the only item of relevance to public safety appears to be the (optional) `fail-safe' feature. The closest that the German microdrones.com site comes to a hint of self-regulation is an FAQ entry that mentions a few built-in safety features - "self-test before takeoff, GPS homing, automatic landing, virtual fence, real-time alert system and automatic safe landing on critical battery level or invalid C&C input". Other entries border on the cavalier: "the microdrone withstand [sic] toughest conditions such as rain or snow, wind up to 15 m/s or even rougher environments ranging from the intense heat of the desert to the icy chill of the Arctic", and "[the drone has been] tested extensively for thermal resistance ... This means that a microdrone can easily fly over a fire". The concept of an operational envelope is applied only in the case of wind, and not in the case of, for example, gusts, temperatures, line-of-sight obstructions or electromagnetic disturbances.

A range of other factors might be considered as indicators of organisational self-regulation at work. For example, manufacturers might publish specific information about the product design features that assure safety, and about the quality assurance processes that provide confidence in the products that take to the air satisfying the design requirements. Manufacturers could publish empirical evidence arising from their testing programs. They could provide safety instructions on or in their products or product packaging, or they could make available videos demonstrating safe and unsafe behaviour. Manufacturers could offer safety courses. They, or their distributors, could conduct research into the regulatory arrangements in each of the jurisdictions that they market into, and make this available to customers, gratis or as a for-fee service. To date, however, little such self-regulatory activity is evident.

5.5 Conclusions

In the jurisdictions considered in the above analysis, it is possible that large drones may be adequately subject to existing formal regulatory arrangements, although some caution is needed in relation to the effectiveness of the transference effects of civil and particularly of criminal laws, and hence about the effectiveness of their deterrent effects. Moreover, careful adaptation of manufacturing and operational Standards will be essential as remotely-piloted flights begin in controlled airspaces.

Serious doubts arise, however, in relation to the regulation of the smaller categories of drone, even in the large and relatively mature contexts of the USA, the EU and Australia. A review of initiatives in the areas of co-regulation, industry self-regulation and organisational self-regulation identified very little in the way of initiatives that might plug the gaps left by inadequate and very-slowly-adaptive formal regulation. The emergent regimes for very small drones may be so lightweight that the public will be left to absorb the negative impacts of drone accidents. In addition, the glacial pace of regulatory adaptation creates a substantial risk of breakouts, and of such laws as exist falling into disrepute.

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6. Prospects for Change

This section considers the possible responses to the problem, firstly at international level, and then within individual jurisdictions.

6.1 At International Level

ICAO has failed to include drones within its international air safety regime, yet it appears that some countries may be waiting for ICAO before adapting their own national laws. They would reasonably see this as having advantages over each country investing in independent research, and unilaterally establishing its own regulatory frameworks, which would then need revision in order to achieve sufficient correspondence with whatever form ICAO's future SARPs take.

A further useful source in framing the debate, although expressed specifically in terms of the US context and the FAA, is Peterson (2005, pp. 95-119). For large drones, it would appear necessary for the rules to be a variant of those already applying to piloted aircraft. For mini- and micro-drones, on the other hand, it might be more appropriate to revise and expand the rules applying to model aircraft and/or ultralight aircraft. Further specialisation will be necessary as nano-drone swarms emerge.

ICAO (2011) stated that "A civil market already exists for UAS. This market will likely remain limited until appropriate regulatory frameworks are in place" (p.8). Many people would regard that as a pious hope, because large numbers of suppliers appear to have large numbers of potential customers eager to conduct relatively inexpensive trials in the hope of establishing business cases for high-payback applications. Many such trials appear to have been conducted in defiance of regulatory regimes, which are perceived as largely nominal anyway.

It may be that JARUS (2013) and outcomes from ICAO's multilateral processes will result in workable Regulations expressed and implemented in all countries in the near future, such that serious incidents are deterred and prevented, or at least are able to be investigated, and blame and liabilities are able to be apportioned, within a credible and coherent framework.

A pessimistic view, on the other hand, would be that drones are being deployed in significant numbers in the absence of a suitable regulatory regime. This creates the prospect of such laws as do exist being found not to be applicable, and not being enforced by regulators and law enforcement agencies - which brings the law into disrepute and undermines public morality. It also leaves open the possibility of serious incidents resulting in kneejerk actions by parliaments to impose inappropriate regulations, with all the deleterious effects such a scenario entails.

The opposite outcome is also possible. Governments and parliaments may cave in to pressure from corporations, industry associations and government agencies that are frustrated by the slowness of the process, resulting in inappropriate de-regulation, which would undermine public safety, and be likely to create even more challenging harmonisation problems than inappropriate over-regulation. Public safety depends on regulatory forces being sufficient to encourage safe practices in the manufacture and deployment of drones, while the future of the industry depends on avoiding unnecessary and unhelpful constraints on the design and use of drones. At the international level, little progress has been achieved towards that objective.

6.2 At National Level

Coherent national strategies may possibly be in place. For example, the FAA's response to the mandate that it was given in 2012 may be managed responsibly, despite the pressure and the challenges of many conflicting perspectives and interests, and the very limited progress apparent to the end of 2013. The parallel processes in the EU and in Australia might also start to bear fruit after slow beginnings.

On the other hand, there are indications of moderate chaos emerging. In the USA, this takes the form of a scatter of incompatible legislation across various States, and proposals for a bounty on drones that are only semi-humorous (Coffman 2013). The Norwegian Board of Technology noted that "At the end of 2012, some 40 Norwegian companies have a license to fly drones, and they operate several thousands of flights per year. Norway has become one of the leading actors in the use and development of drone technology, especially in the maritime sector. If this position is to be maintained, more attention and effort must be dedicated to the development of official rules and regulations guiding the use of drones" (Moe 2013).

In Australia, the discovery of the micro-drone that had crashed into Sydney Harbour Bridge was followed by this meek statement from the regulatory agency: "those operating remotely piloted aircraft must keep them at least 30m away from any people, buildings or structures and to check with local council where they can be used ... [A]irspace around the Harbour Bridge [is] restricted, even for small aircraft such as drones. The onus is on you to operate the machine safely and there are regulations and fines attached ... of hundreds of dollars" (Kontominas 2013). The 30-metre zone is a longstanding requirement in relation to model aircraft (CASA 1998b, p.4 at 7.2.1(f)), although it is subject to exemptions. There is almost no evidence of enforcement. A scan of a sample of local council web-sites found a few By-Laws relating to model aircraft, and mentions of locations where model aircraft clubs have approval to operate. No evidence was found of Councils offering advice on the operation of drones. It is constitutionally unclear whether and to what extent Councils have legal authority in such matters, but what is clear is that they lack the resources and the expertise to enforce any authority they may have.

The public demands much more from its regulatory agencies than a hand-wringing attitude of `This thing is bigger than us. We can't control abuses'. A simple expression of the expectation is that "there need to be stringent, clear, and easily accessible guidelines about how and when these drones can be deployed" (Sharpe 2010). A more comprehensive statement is provided by APF (2013), which specifies a set of meta-principles that were originally developed for privacy-threatening contexts but are equally applicable to the need for public safety. This specifies 5 Principles that relate to the process: Evaluation, Consultation, Transparency, Justification and Audit, and 3 Principles that relate to design: Proportionality, Mitigation and Controls. Application of such a framework, combined with risk assessment techniques, is likely to identify many new segments of domestic airspace in which congestion occurs, including below the current, largely arbitrary 400 feet threshold. The analysis might conclude that some form of air traffic control is becoming essential in such locations, and that 'rules of the road' need to be developed for three dimensional space rather than just two. Further, in order to cope with the reduction in professionalism and licensing, compulsory third-party insurance may have to be imposed.

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7. Conclusions

In Table 2, a set of criteria was proposed for the evaluation of a regulatory regime. In relation to the safety of the public in the face of drone usage, the three forms of `soft law' - self-regulation, industry self-regulation and co-regulation - were all found to be seriously wanting, particularly in relation to the smaller categories of drones.

A strong, clear, highly articulated and well-understood regulatory regime applies to large aircraft, whereas the various categories of smalle drones are subject to a very limited regime which appears to be neither effectively communicated nor enforced. There appears to have been unwillingness on the part of at least some regulators to gather experience by enforcing existing regulations in relation to early, relatively minor incidents. The aims of regulatory reform processes seem not to have been clearly expressed. The discussions held to date do not appear to have evidenced the necessary transparency and hence there are doubts that the framework that emerges will reflect all stakeholders' interests.

Educational processes have not been put in place to communicate to drone manufacturers, to retailers, to the emerging flood of commercial users or to the legions of hobbyists, that they need to undertake risk assessments, devise and implement appropriate safeguards, and establish appropriate commercial arrangements including warranties, maintenance services, and public liability insurance. There does not even appear to be any current momentum towards encouraging hobby users to use their drones within the context provided by model aircraft clubs.

The analysis reported in this paper leads to a number of conclusions that give rise to considerable concern. Much of the world appears to be waiting for ICAO, which moves ponderously. ICAO has declared, with unclear authority, that `model aircraft' and `recreational uses' are outside its scope and are purely a national responsibility. It has not yet commenced considering the appropriate standards for `fully autonomous aircraft operations'. Meanwhile, individual countries are moving very slowly in relation to both the categories of drone that ICAO defines as being national responsibilities and the categories of drone that are not yet even the subject of ICAO deliberations.

The current situation suggests that, as the explosion in drone usage continues apace, a considerable risk exists of preventable harm arising from drone usage.

References

ACLU (2011) 'Protecting Privacy From Aerial Surveillance: Recommendations for Government Use of Drone Aircraft' American Civil Liberties Union, December 2011, at https://www.aclu.org/files/assets/protectingprivacyfromaerialsurveillance.pdf

ACLU (2014) 'Status of Domestic Drone Legislation in the States' American Civil Liberties Union, 22 January 2014, at https://www.aclu.org/blog/technology-and-liberty/status-domestic-drone-legislation-states

ALPA (2001) `Code of Ethics' Air Line Pilots Association International, undated but apparently of 2001, at http://www.alpa.org/Home/WhoWeAre/CodeofEthics/tabid/2262/Default.aspx

AMA (2013) `National Model Aircraft Safety Code', Academy of Model Aeronautics, undated but apparently of 2013, at http://www.modelaircraft.org/files/105.PDF

ANAO (2007) `Administering Regulation: Better Practice Guide' Australian National Audit Office, March 2007, at http://www.anao.gov.au/~/media/Uploads/Documents/administering_regulation_.pdf

Anderson M. & Anderson S.L. (2012) 'Machine Ethics' Cambridge University Press, 2012

APF (2013) 'APF's Meta-Principles for Privacy Protection' Australian Privacy Foundation, March 2013, at http://www.privacy.org.au/Papers/PS-MetaP.html

Armstrong A.J. (2010) `Development of a Methodology for Deriving Safety Metrics for UAV Operational Safety Performance Measurement' Report ,Master of Science in Safety Critical Systems Engineering, Department of Computer Science, York University, January 2010, at http://www-users.cs.york.ac.uk/~mark/projects/aja506_project.pdf

ASA (2013) `How air traffic control works' Air Services Australia, 2013, at http://www.airservicesaustralia.com/services/how-air-traffic-control-works/

ASTM (2013) `F38 - UAS Industry Standards Gap Analysis' American Society for Testing and Materials, undated, but presumably of 2013, at http://www.astm.org/COMMIT/F38_Gap_analysis.ppt

ATSB (2013) `Aviation safety investigations and reports' Australian Transport Safety Bureau, December 2013, at http://www.atsb.gov.au/publications/safety-investigation-reports.aspx?mode=Aviation&sort=OccurrenceReleaseDate&sortAscending=descending&printAll=true

ATSB (2014) `Aviation safety investigations & reports: Investigation number: AO-2013-167' Australian Transport Safety Bureau, updated to 12 February 2014, at http://atsb.gov.au/publications/investigation_reports/2013/aair/ao-2013-167.aspx

AUVSI (2012) 'Industry Code of Conduct' Association for Unmanned Aircraft System Operation, undated, but released July 2012, at http://higherlogicdownload.s3.amazonaws.com/AUVSI/958c920a-7f9b-4ad2-9807-f9a4e95d1ef1/UploadedFiles/AUVSI%20UAS%20Operations%20Code%20of%20Conduct%20-%20Final.pdf and http://www.auvsi.org/conduct

Ayres I. & Braithwaite J. (1992) 'Responsive regulation: Transcending the deregulation debate' Oxford University Press, 1992

Bazelon D.L. (1986) `Governing Technology: Values, Choices, and Scientific Progress, in `Biotechnology in Society: Private Initiatives and Public Oversight', in Perpich J.G. (ed.) 1986, pp. 75-6

BBC (2011) 'Police drone crashes into River Mersey' BBC News, 31 October 2011, at http://www.bbc.co.uk/news/uk-england-merseyside-15520279

Bennett Moses L. (2007) 'Recurring Dilemmas: The Law's Race to Keep Up with Technological Change' University of Illinois Journal of Law, Technology and Policy 7 (2007) 239-285, at http://www.jltp.uiuc.edu/archives/moses.pdf

Black J. (2008) 'Critical Reflections on Regulation' 27 Australian Journal of Legal Philosophy (2002) 1

Braithwaite B. & Drahos P. (2000) `Global Business Regulation' Cambridge University Press, 2000

Brownsword R. (2008) `Rights, Regulation and the Technological Revolution' Oxford University Press, 2008

Brownsword R. & Goodwin M. (2012) `Law in Context: Law and the Technologies of the Twenty-First Century: Text and Materials' Cambridge University Press, 2012

CAA (2012a) `Air Navigation Orders' CAP 393, [UK] Civil Aviation Authority, 3rd Edition, August 2012, at http://www.caa.co.uk/docs/33/CAP393.pdf

CAA (2012b) `Unmanned Aircraft System Operations in UK Airspace - Guidance' CAP 722, [UK] Civil Aviation Authority, orig. Jun 2001, 5th edition, August 2012, at http://www.caa.co.uk/docs/33/CAP722.pdf

CAA (2013) `Model Aircraft: A Guide to Safe Flying' CAP658, [UK] Civil Aviation Authority, orig. December 1995, 4th edition, Jun 2013, at http://www.caa.co.uk/cap658

Calo M.R. (2011) `Open Robotics' Maryland Law Review 70 (2011) 101

Carrigan G., Long D., Cummings M.L. & Duffner J. (2008) `Human factors analysis of predator B crash' Proc. AUVSI: Unmanned Systems North America, at http://www.web.mit.edu/aeroastro/labs/halab/papers/Carrigan_AUVSI.pdf

CASA (1998a) 'Unmanned Aircraft and Rockets: Unmanned Aerial Vehicle (UAV) Operations, Design Specification, Maintenance and Training of Human Resources' Civil Aviation Safety Regulation (CASR) Part 101-1(0), Civil Aviation Safety Authority, original of 1998, current version of July 2002, at http://www.casa.gov.au/wcmswr/_assets/main/rules/1998casr/101/101c01.pdf

CASA (1998b) 'Unmanned Aircraft and Rockets: Model Aircraft' Civil Aviation Safety Regulation (CASR)

Part 101-3(0), Civil Aviation Safety Authority, original of 1998, current version of July 2002, at http://www.casa.gov.au/wcmswr/_assets/main/rules/1998casr/101/101c03.pdf

CASA (2013a) "Development of UAS in civil airspace and challenges for CASA - Address to the Association for Unmanned Vehicle Systems Australia, Melbourne, Civil Aviation Safety Authority, .(Director of Aviation Safety John McCormick), 25 February 2013, at http://www.casa.gov.au/scripts/nc.dll?WCMS:STANDARD::pc=PC_101374

CASA (2013b) 'What is 'Airspace'?' Civil Aviation Safety Authority, 2013, at http://www.casa.gov.au/scripts/nc.dll?WCMS:STANDARD::pc=PC_90449

CASA (2013c) 'List of UAS operator certificate holders' Civil Aviation Safety Authority, 26 April 2013, at http://web.archive.org/web/20130426094414/http://www.casa.gov.au/scripts/nc.dll?WCMS:STANDARD::pc=PC_100959

CASA (2013d) `RPAs (drones) in civil airspace and challenges for CASA' Civil Aviation Safety Authority, 3 July 2013, at http://www.casa.gov.au/scripts/nc.dll?WCMS:STANDARD::pc=PC_101593

CASA (2013e) `Differences between Unmanned Aircraft Systems (UAS) and model aircraft' Civil Aviation Safety Authority, undated but presumably of 2013, at http://www.casa.gov.au/scripts/nc.dll?WCMS:STANDARD::pc=PC_100375

Clarke R. (1988) 'Economic, Legal and Social Implications of Information Technology' MIS Qtly 12,4 (December 1988) 517-9, at http://www.rogerclarke.com/DV/ELSIC.html

Clarke R. (1993) 'Asimov's Laws of Robotics Implications for Information Technology' IEEE Computer 26,12 (December 1993) pp.53-61 and 27,1 (January 1994), pp.57-66, at http://www.rogerclarke.com/SOS/Asimov.html

Clarke R. (1999) `Internet Privacy Concerns Confirm the Case for Intervention', Communications of the ACM, 42, 2 (February 1999) 60-67, at http://www.rogerclarke.com/DV/CACM99.html

Clarke R. (2010) `Civil Society Must Publish Standards Documents' Proc. Human Choice & Computers (HCC9), IFIP World Congress, Brisbane, September 2010, pp. 180-184, at http://www.rogerclarke.com/DV/CSSD.html

Clarke R. (2011) 'Cyborg Rights' IEEE Technology and Society 30, 3 (Fall 2011) 49-57, at http://www.rogerclarke.com/SOS/CyRts-1102.html

Clothier R.A., Palmer J.L., Walker R.A. & Fulton N.L. (2010) `Definition of Airworthiness Categories for Civil Unmanned Aircraft Systems (UAS)' Proc. 27th Int'l Congress of the Aeronautical Sciences (ICAS), September 2010, at http://eprints.qut.edu.au/32789/1/c32789.pdf

Coffman K. (2013) 'Don't like drones? Folks in Deer Trail, Colorado mull paying citizens to shoot them down' Fairfax Media, 18 July 2013, at http://www.theage.com.au/technology/technology-news/dont-like-drones-folks-in-deer-trail-colorado-mull-paying-citizens-to-shoot-them-down-20130718-2q5rd.html

Corcoran M. (2013) 'Drones set for commercial take-off' ABC News, 24 May 2013, at http://www.abc.net.au/news/2013-03-01/drones-set-for-large-scale-commercial-take-off/4546556

Crozier R. (2013) `CASA blasts 'irresponsible' drone bushfire flyover' itNews, 25 October 2013, at http://www.itnews.com.au/News/361940,casa-blasts-irresponsible-drone-bushfire-flyover.aspx

Dalamagkidis K., Valavanis K.P. & Piegl L.A. (2012) 'Unmanned Aircraft Systems Regulation' Chapter in Dalamagkidis K., Valavanis K.P. & Piegl L.A. (eds.) (2012) 'On Integrating Unmanned Aircraft Systems into the National Airspace System' Springer, 2012, pp. 57-90

Drew C. (2010) 'Military Is Awash in Data From Drones' The New York Times, 11 January 2010, at http://csce.uark.edu/~jgauch/library/Video/Drew.2010.pdf

EASA (2012) `Notice of Proposed Amendment (NPA) 2012-10' European Aviation Safety Agency, 21 Aug 2012, at http://www.easa.europa.eu/rulemaking/docs/npa/2012/NPA%25202012-10.pdf

EC (2004) `Insurance requirements for air carriers and aircraft operators' European Union, April 2004, at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do%3Furi%3DOJ:L:2004

EC (2013) 'Roadmap for the integration of civil RPAS into the European Aviation System' European RPAS Steering Group, 20 June 2013, at http://ec.europa.eu/enterprise/sectors/aerospace/files/rpas-roadmap_en.pdf

Elias B. (2012) 'Pilotless Drones: Background and Considerations for Congress Regarding Unmanned Aircraft Operations in the National Airspace System' US Congressional Research Service 7-5700, 10 September 2012, at http://www.fas.org/sgp/crs/natsec/R42718.pdf

EPIC (2005) 'Unmanned Planes Offer New Opportunities for Clandestine Government Tracking' Electronic Privacy Information Center, August 2005, at http://epic.org/privacy/surveillance/spotlight/0805/

EPIC (2012) 'FAA to Assess Safety of Drones in US Airspace' EPIC Alert 19.03, 16 February 16 2012, at http://www.epic.org/alert/epic_alert_19.03.html

EPIC (2013) 'Domestic Unmanned Aerial Vehicles (UAVs) and Drones' Electronic Privacy Information Center, 2013, at http://epic.org/privacy/drones/

FAA (1981) 'Model Aircraft Operating Standards' Advisory Circular 91-57, Federal Aviation Administration, 9 June 1981, at http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/aaim/organizations/uas/coa/faq/media/Order_8130.34.pdf

FAA (2005) 'Unmanned Aircraft Systems Operations in the U.S. National Airspace - Interim Operational Approval Guidance' Federal Aviation Administration, 16 September 2005, at http://www.uavm.com/images/AFS-400_05-01_faa_uas_policy.pdf

FAA (2007) 'Unmanned Aircraft Operations in the National Airspace System: A Rule by the Federal Aviation Administration' Federal Register, 13 February 2007, at https://www.federalregister.gov/articles/2007/02/13/E7-2402/unmanned-aircraft-operations-in-the-national-airspace-system

FAA (2008) 'Airworthiness Certification of Unmanned Aircraft Systems' National Policy Order 8130.34, Federal Aviation Administration, 27 March 2008, at http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/aaim/organizations/uas/coa/faq/media/Order_8130.34.pdf

FAA (2010) 'Fact Sheet - Unmanned Aircraft Systems (UAS)' Federal Aviation Administration, 1 December 2010, at http://www.faa.gov/about/initiatives/uas/media/uas_fact_sheet.pdf

FAA (2013a) 'Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap' Federal Aviation Administration, 7 November 2013, at http://www.faa.gov/about/initiatives/uas/media/UAS_Roadmap_2013.pdf

FAA (2013b) 'Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap' Federal Aviation Administration, 7 November 2013, at http://www.faa.gov/about/initiatives/uas/media/UAS_Roadmap_2013.pdf

FAA (2013c) `FAA Selects Unmanned Aircraft Systems Research and Test Sites' Federal Aviation Administration, 30 December 2013, at http://www.faa.gov/news/press_releases/news_story.cfm?newsId=15576

FAA (2014) `Busting Myths about the FAA and Unmanned Aircraft' Federal Aviation Administration, 26 February 2014, at http://www.faa.gov/news/updates/?newsId=76240

FAI (2001) `Sporting Code Section 12 Unmanned Aerial Vehicles (UAV)' Fédération Aéronautique Internationale, 2001, at http://www.fai.org/downloads/casi/SC12_UAV

GAO (2012) `Unmanned Aircraft Systems: Measuring Progress and Addressing Potential Privacy Concerns Would Facilitate Integration into the National Airspace System' US General Accountability Office, September 2012, GAO-12-981, at http://www.gao.gov/assets/650/648348.pdf

Goth G. (2009) 'Autonomous Helicopters' Communications of the ACM 52, 6 (June 2009) 18-20

Hayes B., Jones C. & Toepfer E. (2014) `Eurodrones Inc.' Statewatch, February 2014, at http://www.statewatch.org/news/2014/feb/sw-tni-eurodrones-inc-feb-2014.pdf

Hepburn G. (2006) `Alternatives To Traditional Regulation' OECD Regulatory Policy Division, undated, apparently of 2006, at http://www.oecd.org/gov/regulatory-policy/42245468.pdf

IACP (2012) `Recommended Guidelines for the use of Unmanned Aircraft', International Association Of Chiefs Of Police, August 2012, at http://www.theiacp.org/portals/0/pdfs/IACP_UAGuidelines.pdf

ICAO (2006) `Exploratory Meeting On Unmanned Aerial Vehicles (UAVs) ' International Civil Aviation Authority, Montréal, 23-24 May 2006, at http://www.icao.int/safety/acp/Inactive%2520working%2520groups%2520library/ACP-WG-C-11/ACP-WGC11-IP07-UAV.doc

ICAO (2011) 'Unmanned Aircraft Systems (UAS)' ICAO Circular 328, International Civil Aviation Organisation, at http://www.icao.int/Meetings/UAS/Documents/Circular%2520328_en.pdf

ICAO (2012) 'Amendment 43 to the International Standards - Rules of the Air (Annex 2 to the Convention)' International Civil Aviation Organisation, March 2012, at http://www.icao.int/Meetings/UAS/Documents/019e.pdf

IACP (2012) 'Recommended Guidelines for the use of Unmanned Aircraft' International Association of Chiefs of Police, Aviation Committee, August 2012, at http://www.theiacp.org/portals/0/pdfs/IACP_UAGuidelines.pdf

ISASI (1983) `Code of Ethics and Conduct' The International Society of Air Safety Investigators, October 1983, at http://isasi.org/Documents/About/isasi_code.pdf

JAA (2004) `Joint JAA/EUROCONTROL Initiative on UAV/ROAs: Final Report' 11 May 2004, at http://www.easa.europa.eu/rulemaking/docs/npa/2005/16-2005/NPA_16_2005_Appendix.pdf

JARUS (2013) `Certification Specification for Light Unmanned Rotorcraft Systems (CS-LURS)' Joint Authorities for Rulemaking on Unmanned Systems, 30 October 2013, at http://jarus-rpas.org/index.php/official-publications?download=24:jarus-cs-lurs-v-1-0

Jordan A., Wurzel R.K.W. & Zito A. (2005) `The Rise of `New' Policy Instruments in Comparative Perspective: Has Governance Eclipsed Government?' Political Studies 53, 3 (September 2005) 477-496

Knight W. (2013) `Driverless Cars Are Further Away Than You Think' MIT Technology Review, November-December 2013, at http://www.technologyreview.com/featuredstory/520431/driverless-cars-are-further-away-than-you-think/

Kontominas B. (2013) 'Security scare as drone hits Bridge' The Sydney Morning Herald, 5 October 2013, at http://www.smh.com.au/nsw/mystery-drone-collides-with-sydney-harbour-bridge-20131004-2uzks.html

La Franchi P. (2006) `Kinshasa UAV accident highlights need for standards development' Flight Global, 9 October 2006, at http://www.flightglobal.com/news/articles/kinshasa-uav-accident-highlights-need-for-standards-209768/

Lin P. (2013) `The Ethics of Autonomous Cars' The Atlantic, 8 October 2013, at http://www.theatlantic.com/technology/archive/2013/10/the-ethics-of-autonomous-cars/280360/

LL (2013) `Drone Crash into Sydney Harbour Bridge Causes Security Incident' Liveleak.com, 26 November 2013, at http://www.liveleak.com/view?i=661_1385456831

Lyndon M.L. (1995) `Tort Law and Technology' (1995) 12 Yale J on Reg 137.

Marks P. (2012) 'GPS loss kicked off fatal drone crash' New Scientist, 18 May 2012, at http://www.newscientist.com/blogs/onepercent/2012/05/gps-loss-kicked-off-fatal-dron.html

Moe A.T. (2013) `Take-off for civilian drones' Norwegian Board of Technology, 19 June 2013, at http://teknologiradet.no/english/take-off-for-civilan-drones/

Mortimer G. (2012) 'Multirotor hits skyscraper and burns, Auckland NZ' sUAS News, 27 October 2012, at http://www.suasnews.com/2012/10/19348/multirotor-hits-skyscraper-and-burns-downtown-auckland-nz/

Niles R. (2013) 'Drone Use List Grows' AVweb, 10 February 2013, at http://www.avweb.com/avwebflash/news/Drone_List_Grows_208143-1.html

O'Neil M. (2013) 'Two Drone-Journalism Programs Seek Federal Approval to Resume Flying' The Chronicle of Higher Education, 27 AUgust 2013, at http://chronicle.com/blogs/wiredcampus/2-drone-journalism-programs-seek-federal-approval-to-resume-flying/45653

PAMA (2012) `AMT Code of Ethics' Professional Aviation Maintenance Association, undated but apparently of 2012, at http://pama.org/node/159

Peterson M.E. (2005) `The UAV and the Current and Future Regulatory Construct for Integration into the National Airspace System' LLM Thesis, McGill University, July 2005, at http://www.dtic.mil/cgi-bin/GetTRDoc%3FAD%3DADA437392

Polinsky A.M. & Shavell S. (2010) `The Uneasy Case for Product Liability' Harvard Law Review 123, 1437

Rip A. (2010) `De Facto Governance of Nanotechnologies' Chapter in in Goodwin M., Koops B.-J. & Leenes R. (eds), `Dimensions of Technology Regulation' Wolf, 2010, pp. 285

RTCA (2013) `List of Available Documents' Radio Technical Commission for Aeronautics, August 2013. at http://rtca.membershipsoftware.org//Files/ListofAvailableDocsMarch2013.pdf

Scott C. (2004) `Regulation in the Age of Governance: The Rise of the Post-Regulatory State' in J. Jordana J. & Levi-Faur D. (eds) `The Politics of Regulation' Edward Elgar, 2004

Sharpe D. (2010) 'Surveillance Drone Grounded Days After Success' Big Brother Watch, 16 February 2010, at http://www.bigbrotherwatch.org.uk/home/2010/02/surveillance-drone-grounded-days-after-success.html

Singer P.W. & Lin J. (2012) 'Baby Steps: The Drone Industry's Code of Conduct Skips Over Key Questions' The Atlantic, 19 July 2012, at http://www.theatlantic.com/politics/archive/2012/07/baby-steps-the-drone-industrys-code-of-conduct-sidesteps-key-questions/260010/

Smith D. (2005) `Unsafe Skies - The Book' Dick Smith, 2005, at http://www.dicksmithflyer.com.au/the_book.php

Spiegel (2013) `Drohne "Luna": Bundeswehr verheimlichte Beinahe-Crash mit Airbus', Der Spiegel, 2 June 2013, at http://www.spiegel.de/politik/deutschland/drohne-luna-bundeswehr-verheimlicht-beinahe-crash-mit-airbus-a-903337.html

ST (2013) 'Unmanned Aircraft Systems (UAS) Comprehensive Plan: A Report on the Nation's UAS Path Forward' US Secretary for Transportation, September 2013, at http://www.faa.gov/about/office_org/headquarters_offices/agi/reports/media/UAS_Comprehensive_Plan.pdf

Stuurman K. & Wijnands H. (2001) 'Software Law: Intelligent Agents: A Curse or a Blessing? A Survey of the Legal Aspects of the Application of Intelligent Software Systems' Computer Law & Security Review 17, 2 (March 2001) 92-100

T&D (2012) 'Animal rights group says drone shot down' T&D, 14 February 2012, at http://thetandd.com

/animal-rights-group-says-drone-shot-down/article_017a720a-56ce-11e1-afc4-001871e3ce6c.html

Table of Statutes

International Treaties

'Convention on International Civil Aviation' (the Chicago Convention), United Nations, 1944, Doc 730019, 9th Edition 2006
http://www.icao.int/publications/Documents/7300_cons.pdf

`Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface' (the Rome Convention), International Civil Aviation Authority, Montréal, 1952
http://www.icao.int/secretariat/legal/List%20of%20Parties/Rome1952_EN.pdf

USA

Restatement of the Law Third, Torts: Products Liability
http://www.ali.org/ali_old/promo6081.htm

Nev. Rev. Stat. Ch. 482A
http://www.leg.state.nv.us/Session/76th2011/Bills/AB/AB511_EN.pdf

Federal Aviation Regulations (FARs)
/http://www.faa.gov/regulations_policies/faa_regulations/

FAA Air Transportation Modernization and Safety Improvement Act of 2012
http://www.gpo.gov/fdsys/pkg/CRPT-112hrpt381/pdf/CRPT-112hrpt381.pdf

EU

Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products
http://europa.eu/legislation_summaries/consumers/consumer_safety/l32012_en.htm

Regulation (EC) No 216/2008 of the European Parliament and of the Council', 20 February 2008, with amendments to 24 November 2009
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2008R0216:20091214:EN:PDF

Regulation (EC) No 785/2004 of the European Parliament and of the Council of 21 April 2004 on insurance requirements for air carriers and aircraft operators
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004R0785:EN:HTML

Directive 2009/48/EC of the European Parliament and of the Council of 18 June 2009 on the safety of toys
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0048:EN:NOT

Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008R0216:EN:NOT

Australia

The Australian Consumer Law
Competition and Consumer Act 2010 (Cth), Schedule 2
http://www.austlii.edu.au/au/legis/cth/consol_act/caca2010265/sch2.html

The Criminal Code Act 1995 (Cth), Schedule 1:
http://www.austlii.edu.au/au/legis/cth/consol_act/cca1995115/sch1.html

Telecommunications (Interception and Access) Act 1979 (Cth)
http://www.austlii.edu.au/au/legis/cth/consol_act/taaa1979410/s7.html

Air Navigation Act 1920 (Cth)
http://www.austlii.edu.au/au/legis/cth/consol_act/ana1920148/

Air Navigation Regulations 1947 (Cth)
http://www.austlii.edu.au/au/legis/cth/consol_reg/anr1947257/

Civil Aviation Act 1988 (Cth)
http://www.austlii.edu.au/au/legis/cth/consol_act/caa1988154/index.html
http://flysafe.raa.asn.au/regulations/civilact.html

Civil Aviation Regulations 1988 (Cth) (CAR)
http://www.austlii.edu.au/au/legis/cth/consol_reg/car1988263/index.html

Civil Aviation Safety Regulations 1998 (Cth) (CASR)
http://www.austlii.edu.au/au/legis/cth/consol_reg/casr1998333/index.html#s1.001

Damage by Aircraft Act 1999 (Cth)
http://www.austlii.edu.au/au/legis/cth/consol_act/dbaa1999139/

Radiocommunications Act 1947 (Cth)
http://www.austlii.edu.au/au/legis/cth/consol_act/ra1992218/

Telecommunications (Interception and Access) Act 1979 (Cth)

http://www.austlii.edu.au/au/legis/cth/consol_act/taaa1979410/

N.S.W.

Crimes Act 1900 (NSW)
http://www.austlii.edu.au/au/legis/nsw/consol_act/ca190082/index.html

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