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

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 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 and micro-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.

The application of drones in civilian contexts creates the prospect of a wide range of benefits. It also creates new sources of harm through 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 and Crozier 2013 in Australia). On the other hand, in one case in Korea a death 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 only potentially hazardous objects using airspace. There are therefore many existing rules that are designed to achieve air safety and provide for compensation where harm does result. This paper considers whether these rules satisfactorily address drone-related safety problems.

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 research reported on in this series of papers has identified two particular areas of impact that are in urgent need of assessment: public safety, and behavioural privacy. The focus of this, the third paper in the series, is the current regulatory framework relating to public safety. The fourth paper conducts a similar analysis focussing 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.

This paper commences by summarising the risks to public safety that were surfaced by the first two papers in the series, and considers the extent to which natural controls act to limit harm arising from those risks. It then draws on the literature to identify alternative approaches to regulation. The regulation of drones' threats to public safety is then assessed against that framework, commencing with consideration of international conventions and the laws of several key countries. This is followed by an evaluation of the contributions of 'soft' forms of regulation to public safety. Finally, the prospects are reviewed of effective regulatory frameworks being in place as drone adoption accelerates.

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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 An important factor that impacts on the existence and extent of many of the risks is the physical, personal and organisational distance that separates the drone's operator from the drone's behaviour. 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 at least some appreciation of the prevailing conditions and of relevant national, regional and local cultures
- **a remote pilot**, who is much more likely to lack a sense of immediacy, involvement and personal responsibility, but who still brings with them the possibility of 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 even without any scope for intervention by a human

As with any airborne object, potential harms to public safety from drones include 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. It is not only physical impacts that threaten assets. Operation of a drone or its onboard facilities may impair the function of some other device, person or organisation, for example through transmission of electromagnetic radiation. Drones' dependence on continual feeds of data and commands make them a source of interference with the electromagnetic signals on which other devices depend.

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 deliberately disrupt other activities. Motivations for deliberate harm include revenge, thrill -seeking, as an aid in 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 physically attack using a projectile including attack by another drone.

Some incidents might be unintended, but be a foreseeable consequence of drone deployment. For example, pilot error 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 drone malfunctions are a result of environmental incidents, in insurance parlance 'Acts of God', which are foreseeable but unpreventable, such as severe turbulence and lightning.

Most of these circumstances can arise with manned aircraft. While interference with software is a particular challenge for drones, any airborne vehicle may be 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, the consequential high volume of drone activity that can be reasonably anticipated, and the high costs involved in detection, investigation, and sheeting home responsibility. The reduction in drone costs has been so significant that the capital needed to mount attacks is very low, and the drones themselves are expendable. 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.

At the same time as drones are likely to become more pervasive due to their low cost, 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, giving rise to the need for inexpensive-but-effective onboard collision avoidance facilities. Physically congested airspace will also be electronically congested, resulting in high levels of signal interference and hence drones that are receiving unreliable and intermittent data- and control-streams. In controlled airspace, drones create new challenges for the interactions between pilots 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 directly connected and hence dependent on additional elements, which represent 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 military, industrial and some commercial purposes involve substantial investment, including in quality. 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', 'crowdsourced documentation' and 'permanent beta' 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.

Many of the threats and vulnerabilities are significantly increased as the pilot shifts from onboard, to adjacent, to remote. This is particularly the case where concentration is a factor, where rapid and finely-judged response may be needed amidst long periods of boredom, in 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.

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 fail-soft or fallback 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 and has far fewer degrees of freedom to cope with. They nonetheless need to 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 needed. In some circumstances, the natural controls may even be sufficiently effective, and the residual risk sufficiently limited, that active regulatory measures may 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 or volcanic eruption. Other sources of danger include congestion in the airspace and in electronic spectrum depended on for drone control. Danger to the pilot's personal safety mostly acts as a strong deterrent against irresponsible behaviour, and that is generally reinforced by the potential financial consequences. In the case of drones, however, the pilot is not on board; and in the case of nano- and micro-drones and even small drones, the investment that is at risk may not be so great as to represent a major influence on the decision to fly. 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 aircraft operators. Organisations and individuals that operate aircraft have to have access to considerable financial means. They are readily discoverable, including in most contexts through registration and licensing schemes, and hence there is a reasonable prospect that such organisations will be held accountable for costs arising from accidents and negligence. 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.

These economic forms of control may 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, but not so powerful that they can avoid responsibility. On the other hand, small 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 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 may be 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. 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

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 South Pylon of 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).

The natural controls discussed above do not represent sufficiently effective safeguards, and considerable residual risks exist. The volume of drone activity appears set to increase rapidly in the near future, and hence examination of regulatory arrangements is warranted. The following section reviews regulatory theory, in order to establish a framework for the analysis.

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3. Regulation and Technological Change

The focus of this paper is on regulatory arrangements for drones relating to public safety, in particular laws relating to violent or physically harmful acts in civilian contexts, and the management of airspace. The fourth paper in the series considers the regulatory arrangements to protect behavioural privacy against drone-based surveillance.

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 defines it 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 markets and weather, and focus on deliberate attempts to achieve particular outcomes by influencing behaviour. The ANAO definition is adopted, with `instruments' interpreted broadly.

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.

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' continue to be subject to formal regulation or `government' , whereas the limited regulatory frameworks applicable to model aircraft and drones are at the very mild end of `soft law' or `governance'.

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

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

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 controlling 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

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, employers of pilots, 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 the authors' home-country, Australia, with consideration then given to the extent to which laws elsewhere are similar to, and differ from, those in that country.

4.1 Risk Management

The concepts and processes of risk assessment and risk management are well-known, to the extent of being subject to multiple Standards, and supported by multiple proprietary products. The outcome of these processes is a risk management plan, which identifies safeguards that are to be adapted and added, in order to address the risks that are identified as being of primary concern.

The many approaches that can be adopted to any particular risk 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 means of limiting the period over which the harm is suffered. 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, which 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 is 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 sheets home financial responsibility to 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. Further factors that affect the extent to which constructive approaches are encouraged include the size and power of the party. Imposing criminal responsibility for inappropriate behaviour also has the effect of encouraging the adoption of proactive strategies - which are sometimes constructive strategies that are to the advantage of regulatory beneficiaries, as well as to the regulatees.

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 be relevant 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.

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 resulting 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).

For product liability and negligence to be effective transferrence 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, for new technologies generally, and for drones in particular.

4.3 Criminal Laws

Criminal law, where it applies, may not achieve any transferrence 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 pilot 'driving' offences, 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:

- 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; and
- the offence of assault on 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.

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

Considerable differences exist among jurisdictions in such areas of law. In many jurisdictions, the technological features of drones may generate uncertainties and looholes. 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 very 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 possession or operation 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 transferrence mechanism. It is unclear whether they will have a significant deterrent effect against any of 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 such generally applicable laws exist and are effective. However, it appears unlikely that many such analyses would result in clear and confident expressions to the effect that laws have comprehensively and effectively anticipated the need for a regulatory framework for drones.

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, technical complexity, and 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 in the preceding section: formal regulation, co-regulation, industry self-regulation and organisational self-regulation.

5.1 Formal Regulation - Air Safety Laws

Formal regulatory frameworks comprise statutes, 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.

The focus of aviation regulation has always been on piloted aircraft, above a given size and generally operating above a given height and in sectors adjacent to airports. Other aircraft, such as what are commonly termed 'model aircraft', are subject to national laws.

The longstanding approach to managing risk in congested airpsace, 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 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
- a 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 physical congestion, and electronic congestion, which in turn threatens data quality, and risks information overload on both air traffic controllers and their supporting infrastructure.

The 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.

A further 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 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 Standards for drones is provided in Peterson (2005, pp. 49-63). Rules for the operation of 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, chaired by an Australian, 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:

- 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.
- RPAS shall meet the performance and equipment carriage requirements for the specific airspace in which the flight is to operate.
- An RPAS shall be approved ...
- An operator shall have an RPAS operator certificate ...
- 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 micro-drones; nor for different obligations relating to commercial uses and to personal uses. It may be that ICAO treats `other-than-commercial', `recreational' 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 IACO 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, 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 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, it has a single national jurisdiction (which makes the analysis much simpler than is the case with the EU), it has a relatively small number of major airports and only moderately congested airspace (making it a 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 small, recreational devices, commonly referred to as 'model aircraft' has been subject to regulation for many years. There are 11 pages of statute and 16 pages of Regulations, referred to as CASR -101-3, which is greatly scaled-down requirement in comparison to pilot-on-board aircraft. They contain no requirements for model aircraft registration, pilot licensing or model aircraft airworthiness certification (CASA 1998b).

CASA is understood to have been the first national agency to issue operational regulations for drones, as CASR Regulation 101-1 (CASA 1998a, applicable since 2002). An overview is provided in Peterson (2005, pp. 81-87). "In 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). However, "Provided that a small UAV is operated not above 400 ft AGL [undefined in the document, but presumably 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).

CASR 101-1 leaves important elements subject to unreferenced authorities or uncertain interpretations:

- "clear of ... aerodromes" is interpreted in CASA speeches as being "three nautical miles"
- the same speeches appear to interpret "clear of ... populous areas" as "30 meters from people"
- the absence of a definition 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 `3 nautical miles from aerodromes', '30 meters from people' and `150kg' thresholds are mentioned in CASR 101-3 applying to model aircraft, but do not appear in CASR 101-1 applying to drones.

It is possible that this existing regulatory regime will 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, most with spinning blades, 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 mass of such a drone is 14-50 times that of a cricket-ball, cricket balls have a predictable and narrow 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 guidance appears to be provided.

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).

Concerns arise from time to time about 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 have been levelled at CASA and ATSB of inadequate standards and inadequate responses to incidents, including by a sometime Chair of CASA (Smith 2005).

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.

In short, the specific laws regulating the flight of drones in Australia are complex. No overview could be located on the CASA web-site. Table 3 was accordingly inferred from various documents, in order to identify the particular Regulations that are applicable under various circumstances. It is expressed in the conventional form of a decision table.

Table 3: Regulatory Frameworks Applying to Drones in Australia

DETERMINATIVE FACTORS						
Controlled Airspace	√	–	X	X	X	X
> 150kg Fixed-Wing / 100kg Rotorcraft	–	√	X	X	X	X
< 150kg Fixed-Wing / 100kg Rotorcraft	–	X	√	√	√	√
Commercial Use	–	–	√	X	X	X
2-7 kg	–	X	X	X	√	X
< 2kg	–	X	X	X	X	√
APPLICABLE REGULATORY REGIME						
Full Regulatory Framework (CASR)	√	√	–	–	–	–
Limited Regulatory Framework (CASR 101-1)	–	–	√	–	–	–
Model Aircraft Framework (CASR -101-3)	–	–	–	√	√	√
(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.

(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 2013, 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 (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). 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 2013, 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, forced the organisation's hand, by mandating that the FAA:

- begin allowing law enforcement use of small drones (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. Halfway through the 43 months originally allowed for compliance with the second mandate, very little has 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 2013). Unfortunately, the road continues to be paved with mud. The Roadmap is 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 2013, 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 on 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 on 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 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 intended regulatees and 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 variety of Bills being tabled in State legislatures, and a few even being passed. These are catalogued by ACLU (2013). A substantial review of regulatory developments is in Dalamagkidis et al. (2012). See also 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 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.

On the other hand, a document published by a large group of 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)

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 aicraft, a separate, shorter and simpler publication applies (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 (CAA 2012a).

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

(5) Conclusions

In relation to piloted aircraft, at least in each of the USA, Europe and Australia, a regulatory agency exists, has suitable 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 extends to drones operating in controlled airspace, and to large drones.

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 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 well-informed, and are meaningful to regulatees, 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 by regulatees over the regulator. Some balance between the two extremes can in principle be achieved where stakeholders other than the industry are also empowered, and the relevant parliament and government credibly wield the power to abandon the co-regulatory approach and impose formal regulation. That condition 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. Although Europe is generally regarded as having more inclusive processes, neither EASA (2012) nor EC (2013) show much evidence of engagement with stakeholders outside the industry.

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 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, from 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 had stalled, because a new Committee was formed in May 2013 (SC-228 Minimum Operational Performance Standards [MOPS] for Unmanned Aircraft Systems). Initial White Papers are scheduled for December 2013 and July 2015, and hence finalisation of MOPS is quite some years away. It is unclear to what extent this initiative is coordinated with international activities, and it does not appear that the scope extends to micro-drones.

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.

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 much-delayed.

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 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 the general aviation industry and insufficient action within the drone industry itself. A primary organisation of the relevant kind is the Association for Unmanned Vehicle Systems International (AUVSI). One reference traces this 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 my member-corporations, let alone creates any obligations, let alone extends 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 form of user segment association nonetheless. The International Association of Chiefs of Police 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.

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.

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 the manufacture of drones, through its Committee F38 on Unmanned Aircraft Systems (UAS). These can be located by searching for <UAS> on the organisation's web-site. No catalogue showing dates of publication has been located, 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 their application through 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 author has seen nothing to suggest that a similar call in 2013-14, 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 and 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 whereby public safety is ensured.

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 closest that the 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, 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 transferrence 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 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.

The technology is maturing at a far more rapid rate than the social and legal institutions that are meant to protect public safety.

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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 its own comprehensive 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 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.

It may be that outcomes from the JARUS and ICAO multilateral processes are imminent, and that workable Regulations will be expressed and implemented in all countries in the very near future, before serious incidents arise, 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 regulatory progress is glacial, while technical and economic progress is dynamic. This creates the prospect of unrealistic laws 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.

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. 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 'regulator': "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. He said airspace around the Harbour Bridge was 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. It is unclear whether it is enforced. A scan of a sample of local council web-sites found no evidence of public information about drones, or even about model aircraft. The sole reference of relevance that was found was a response to an enquiry from a constituent in July 2013, declaring that inner-east-Melbourne Yarra City Council "does not yet have a policy relating to drones".

The public demands much more from its regulatory agencies than a hand-wringing attitude of 'we can't control it'. 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.

The strong, clear, highly articulated and well-understood regulatory regime that applies to aviation generally is currently at best only applicable to smaller drones in a much scaled-down manner. The aims of regulation have not 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. 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.

No educational processes appear to be in place to communicate to drone manufacturers, retailers and commercial users 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:

- the world is waiting for ICAO
- ICAO is moving ponderously
- ICAO has declared, with unclear authority, that `model aircraft' and `recreational uses' are outside its scope and are purely a national responsibility
- ICAO has indicated that it has not yet commenced considering the appropriate standards for `fully autonomous aircraft operations'
- individual countries are moving ponderously in relation to:
  - the categories of drone that ICAO defines as being national responsibilities
  - the categories of drone that are not yet even the subject of ICAO deliberations

The current situation, some years into the drone explosion, might reasonably be described as primitive.

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