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PREDICTING BEARING FAULT IN THE DRONE FREIGHT INDUSTRY: LEGAL LIABILITY IN AUSTRALIA

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ABSTRACT

Many people are now aware of drones or remotely piloted aircraft (RPAs), and several others have predicted the significant impacts that drones will bring across society. Today, there is an expectation that drones will play a pivotal role in industries such

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as surveillance, security, surveying, construction, and freight transport. However, in all these cases, whenever a drone is flying over a populated area, it poses a danger to people or things on the ground. Perhaps the sector where the greatest risk of injury to the everyday person exists is the drone delivery industry. The drone freight industry is proliferating fast, with many companies like Skycart and Amazon investing in this sector. These companies plan to transport groceries, medical supplies, food, and parcels, among many other things. If fleets of delivery drones are deployed around suburbs, the descent to lower altitudes and the general logistics of an airborne delivery presents a novel risk of harm. A drone failure resulting in a crash could lead to property damage, destruction of natural environments, and injury or death to persons, especially in areas of high population density. One promising way to prevent such harm is to use structural condition monitoring technology to preempt any deterioration of the airworthiness of a drone. In the absence of any existing precedent or authority on this, this Article investigates the legal implications of using such technology to guide future regulations and areas of research.

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I. INTRODUCTION

DRONES, OR "REMOTELY PILOTED AIRCRAFT" (RPAs),[1] are fast becoming prevalent across various industries, in-

[1] We use the term "drone" and "RPA" interchangeably in this Article. However, it should be noted the term "drone" is not largely used by regulators inter-

cluding agriculture, engineering, construction, energy, security, and law enforcement.[2] However, continuing advancements in engineering are seeing drones progress to increasingly versatile and innovative applications beyond aerial scanning tools. There is now significant discussion about drones revolutionizing transport, delivery, and logistics systems.[3] This Article considers how condition monitoring of drone bearings might affect the liability of freight drones in Australia.

With developments in technological capability, navigation technology, hardware performance, and lower costs, the commercial adoption of drones is soaring.[4] In 2020, the worldwide demand volume of drones eclipsed 689,400 units, valuing the commercial drone market at U.S. $13.44 billion.[5] It is estimated

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nationally or in Australia. Previously, the term Unmanned Aerial Vehicle (UAV) was used in Australian regulations; however, the *Civil Aviation Legislation Amendment (Part 101) Regulation 2016* (Cth) (Austl.) updated the terminology in part 101 of the *Civil Aviation Safety Regulations 1998* (Cth) (Austl.) to align it with terminology of the International Civil Aviation Organization, including replacing UAV with RPA. Other alternative terms used in this Article include remotely piloted vehicle (RPV), remotely operated aircraft (ROA), or uncrewed aircraft (UA). At the time this Article was written, the FAA term in use was unmanned aircraft, with a proposal to change the regulatory term to uncrewed aircraft. DRONE ADVISORY COMM., FED. AVIATION ADMIN., PUBLIC EBOOK JUNE 23, 2021 DAC MEETING 104, 113 (2021), https://www.faa.gov/uas/programs_partnerships/drone_advisory_committee/media/DAC_Public_eBook_06_23_2021.pdf [https://perma.cc/8C4G-3W5S].

[2] *Drone Technology Uses and Applications for Commercial, Industrial and Military Drones in 2021 and the Future*, BUS. INSIDER [hereinafter *Drone Technology Uses*], https://www.businessinsider.com/drone-technology-uses-applications [https://perma.cc/G2NG-XA8F] (Jan. 12, 2021, 10:15 AM).

[3] Atsushi Oosedo, Hiroaki Hattori, Ippei Yasui & Kenya Harada, *Unmanned Aircraft System Traffic Management (UTM) Simulation of Drone Delivery Models in 2030 Japan*, 33 J. ROBOTICS & MECHATRONICS 348, 348 (2021); Rico Merkert & James Bushell, *Managing the Drone Revolution: A Systematic Literature Review into the Current Use of Airborne Drones and Future Strategic Directions for Their Effective Control*, 89 J. AIR TRANSP. MGMT., 2020, at 1, 5; DELOITTE ACCESS ECON., AUSTL. DEP'T OF INFRASTRUCTURE, TRANSP., REG'L DEV. & COMMC'NS, ECONOMIC BENEFIT ANALYSIS OF DRONES IN AUSTRALIA: FINAL REPORT 25–27 (2020), https://www2.deloitte.com/content/dam/Deloitte/au/Documents/public-sector/deloitte-au-ps-economic-benefit-analysis-of-drones-to-australia-11112021.pdf [https://perma.cc/6YLF-DMSQ].

[4] *Drone Technology Uses*, *supra* note 2.

[5] *See Commercial Drone Market Size, Share & Trends Analysis Report by Product (Fixed-Wing, Rotary Blade, Hybrid), by Application, by End-Use, by Region, and Segment Forecasts, 2021 - 2028*, GRAND VIEW RSCH. (Apr. 2021) [hereinafter *Drone Analysis Report*], https://www.grandviewresearch.com/industry-analysis/global-commercial-drones-market [https://perma.cc/7RAB-GGYA].

this will grow at a further compound annual growth rate (CAGR) of 57.5% from 2021 to 2028.[6]

A significant part of this exponential growth will be derived from the freight industry, which despite only being the third largest component of the commercial drone market,[7] is the area of the market anticipated to exhibit the highest growth at a projected CAGR of over 60% from 2021 to 2028.[8] Bolstered by wider societal tailwinds, such as the continuing adoption of e-commerce and technology, the value of the global drone package delivery market is expected to grow from $532 million U.S. dollars in 2020 to $11,519 million in U.S. dollars by 2027.[9]

This growth is underpinned by the freight industry's significant commercial opportunities currently available.[10] Drones can save time, reduce costs, and generally increase productivity in novel ways.[11] This is achieved by taking advantage of unused airspace zones, thus omitting the need to resort to significant capital investments in urban infrastructure.[12] The result is a freight service that is a faster and greener alternative to increasingly congested roadways.

A mix of blue-chip companies, startups, and leading vendors are seeking to tap into this commercial opportunity.[13] Unlike hobbyists, these companies invest substantial sums of money into research and development to equip their drones with state-

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6 *Id.*

7 PwC, CLARITY FROM ABOVE: PWC GLOBAL REPORT ON THE COMMERCIAL APPLICATIONS OF DRONE TECHNOLOGY 4 (2016), https://www.pwc.pl/pl/pdf/clarity-from-above-pwc.pdf [https://perma.cc/UG9N-5QD4].

8 *Drone Analysis Report*, *supra* note 5.

9 360iResearch, *Drone Package Delivery Market Research Report by Type, by Duration, by Range, by Package Size, by End-Use, by Region - Global Forecast to 2027 - Cumulative Impact of COVID-19*, REPORTLINKER (Jan. 2022), https://www.reportlinker.com/p06168777/Drone-Package-Delivery-Market-Research-Report-by-Type-by-Duration-by-Range-by-Package-Size-by-End-Use-by-Region-Global-Forecast-to-Cumulative-Impact-of-COVID-19.html [https://perma.cc/SH6A-9KHA].

10 Merkert & Bushell, *supra* note 3, at 5.

11 *Drone Technology Uses*, *supra* note 2.

12 *See id.*; DAVID HODGKINSON & REBECCA JOHNSTON, AVIATION LAW AND DRONES: UNMANNED AIRCRAFT AND THE FUTURE OF AVIATION 57 (2018).

13 360iResearch, *supra* note 9 (including Airbus S.A.S., Altitude Angel, Amazon.Com, Inc., Bizzby, Boeing, Cheetah Logistics Technology, Deutsche Post Dhl Group, Drone Delivery Canada Corp., Dronescan, Edronic, Ehang, Elroy Air, Fedex, Fli Drone, Flirtey, Flytrex, Manna Aero, Matternet, Inc., Rigi Technologies Sa, Skycart Inc., Skyports Limited, Speedbird Aero, United Parcel Service of America, Inc., Volansi, Wing Aviation LLC, Wingcopter, Workhorse Group Inc., and Zipline).

of-the-art technology.[14] The purpose of this investment is not just for business efficiency but also to protect themselves from the inherently greater legal, economic, and regulatory risks that accompany commercial operations.[15] For drones to gain widespread acceptance from a policy perspective, the technology must be reliable, and adverse incidents should be minimal.[16] In their most recent policy statement, the Australian government has recognized that "[t]echnical and procedural solutions" are options to achieve acceptable levels of safety performance for drones.[17]

Different technologies aim to solve different types of risks. In aviation, risks are split into two categories: air risks (drones colliding with other aircraft) and ground risks (drones colliding with a person or property on the ground).[18] Aerial avoidance technology includes geo-fencing, sense-and-avoid technologies, and other transponder-based systems, such as Automatic Dependent Surveillance-Broadcast (ADS-B),[19] while ground damage mitigation measures include structural condition monitoring,[20]

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[14] *Drone Technology Uses*, *supra* note 2.

[15] *See, e.g.*, *How to Properly Insure Your Drone Business*, EMBROKER (Nov. 19, 2021), https://www.embroker.com/blog/drone-insurance/ [https://perma.cc/2W43-59B2].

[16] *See Drone Technology Uses*, *supra* note 2.

[17] *See* AUSTL. DEP'T OF INFRASTRUCTURE, TRANSP., REG'L DEV. & COMMC'NS, NATIONAL EMERGING AVIATION TECHNOLOGIES: POLICY STATEMENT 19 (2021) [hereinafter POLICY STATEMENT], https://www.infrastructure.gov.au/sites/default/files/migrated/aviation/technology/files/national-emerging-aviation-technologies-policy-statement.pdf [https://perma.cc/HJ3Y-GFA5].

[18] AUSTL. DEP'T OF INFRASTRUCTURE, TRANSP., REG'L DEV. & COMMC'NS, EMERGING AVIATION TECHNOLOGIES: NATIONAL AVIATION POLICY ISSUES PAPER 23 (2020) [hereinafter POLICY ISSUES], https://www.infrastructure.gov.au/sites/default/files/migrated/aviation/technology/files/drone-discussion-paper.pdf [https://perma.cc/4L3W-RWSS].

[19] For an overview of these technologies, see AUSTL. SENATE, RURAL & REG'L AFFS. & TRANSP. REFERENCES COMM., PARLIAMENT OF AUSTL., CURRENT AND FUTURE REGULATORY REQUIREMENTS THAT IMPACT ON THE SAFE COMMERCIAL AND RECREATIONAL USE OF REMOTELY PILOTED AIRCRAFT SYSTEMS (RPAS), UNMANNED AERIAL SYSTEMS (UAS) AND ASSOCIATED SYSTEMS 77–78 (2018) [hereinafter AUSTL. SENATE INQUIRY], https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Rural_and_Regional_Affairs_and_Transport/Drones/~/media/Committees/rrat_ctte/Drones/report.pdf [https://perma.cc/D6BB-UL83].

[20] Yong Keong Yap, Structural Health Monitoring for Unmanned Aerial Systems (May 14, 2014) (Master's thesis, University of California, Berkeley) (Technical Report No. UCB/EECS-2014-70), http://www.eecs.berkeley.edu/Pubs/TechRpts/2014/EECS-2014-70.html [https://perma.cc/DXQ9-6B2N].

parachutes,[21] automatic descent functions, and redundancy systems.[22] Currently, most of these technologies are still being developed and perfected.

This Article focuses primarily on ground risks and using structural condition monitoring technology to mitigate these risks, specifically that of a bearing health monitoring device. The scope of this Article is kept within the confines of tort law, based on commentary from the literature that in the case of emerging technologies—where specific strategies for managing risk are rarer—tort law provides a useful feedback environment and signal for future regulation.[23]

Part II of this Article begins by contextualizing the current state of drone technology that is being used to mitigate ground damage. It is proposed that there exists both an engineering and legal impetus for using structural condition monitoring technology on drones. Part III then delves into a technical examination of drones and the broader regulatory framework within which drones currently operate. It argues that it is likely that a bearing condition monitoring device will greatly contribute to satisfying many general regulatory requirements. In Part IV, the law of liability is discussed, first with a review of legislation and regulations and then an evaluation of the common law. In regard to legislation, it is currently found that, because of the strict liability or no-fault nature of the applicable legislation, a bearing condition monitoring system will not operate as a complete legal shield in the event of harm to persons or property. Nonetheless, a monitoring system will still be of use in ensuring the drone does not fall in the first place, which would avoid liability altogether. As to the common law, it is hypothesized that using bearing condition monitoring technology in certain circumstances will be enough to determine that the drone operator or manufacturer is not at fault; however, this will depend on

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21 Basem AL-Madani, Marius Svirskis, Gintautas Narvydas, Rytis Maskeliunas & Robertas Damaševicius, *Design of Fully Automatic Drone Parachute System with Temperature Compensation Mechanism for Civilian and Military Applications*, J. ADVANCED TRANSP., Nov. 2018, at 1, 2.

22 In engineering, a redundancy is the duplication of critical components and functions to increase reliability of a system. Sam, *What Is a Redundant System and How Do Drones Use Them?*, DRONESVILLA (Nov. 29, 2019), https://www.dronesvilla.com/what-is-a-redundant-system/ [https://perma.cc/D543-BM6K].

23 *See generally* Mary L. Lyndon, *Tort Law and Technology*, 12 YALE J. ON REGUL. 137 (1995); Roger Clarke & Lyria Bennett Moses, *The Regulation of Civilian Drones' Impacts on Public Safety*, 30 COMPUT. L. & SEC. REV. 263, 270 (2014).

the cause of action and specific circumstances of each case. Part V concludes the Article.

II. CONDITIONAL MONITORING OF BEARINGS TO MITIGATE LEGAL RISK

Across most industries, especially in the freight sector, damage on the ground from a drone is arguably the most significant risk to consider and the risk most likely to have legal consequences.[24] Air risks pose less of a concern because drones operate in "urban canyons," or the airspace in between the tops of buildings and the ground, and given that no crewed aircraft currently operates in that zone, there is a comparatively low risk of collision.[25] Even then, any aerial collision, whether with buildings, drones, or aircraft, will still ordinarily lead to a ground risk as debris or the drone itself falls to the ground.[26] Sharp rotor edges and mechanical parts, in combination with high speeds and elevated altitudes, mean that even the smallest of drones can cause lethal kinetic force.[27] Where freight drones are concerned, the increased payloads, the vast distances covered, and the greater frequency of everyday use over populated areas exacerbate such risks.[28]

Thus, if drone freight operations are to become routine in cities, it will be essential to minimize the risk of drones falling to the ground.[29] The main issue across all drones is that they rely on propellers to stay in the air—the failure of which may impact safety.[30] In a drone, electric motors spin the propellers to keep

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[24] *See* HODGKINSON & JOHNSTON, *supra* note 12, at 34.

[25] *Id.* at 57.

[26] *See* Xuejun Zhang, Yang Liu, Yu Zhang, Xiangmin Guan, Daniel Delahaye & Li Tang, *Safety Assessment and Risk Estimation for Unmanned Aerial Vehicles Operating in National Airspace System*, J. ADVANCED TRANSP., Oct. 2018, at 1, 2–3.

[27] Henry H. Perritt, Jr., *Who Pays When Drones Crash?*, 21 UCLA J.L. & TECH. 1, 69 (2017); HODGKINSON & JOHNSTON, supra note 12, at 23–24.

[28] Submission from Maurice Thompson, Anthony Tarr & Julie-Anne Tarr to Austl. Dep't of Infrastructure, Transp., Reg'l Dev. & Commc'ns, Emerging Aviation Technologies: National Aviation Policy Issues Paper 4 (Oct. 22, 2020), https://www.infrastructure.gov.au/sites/default/files/migrated/aviation/technology/files/submission-06-2020-10-22-clyde-co-ltr-to-director-airspace-and-emerging-technologies.pdf [https://perma.cc/2Y8A-S3XT].

[29] *See, e.g.*, Julie-Anne Tarr, Maurice Thompson & Anthony Tarr, *Regulation, Risk and Insurance of Drones: An Urgent Global Accountability Imperative*, 8 J. BUS. L. 559, 563 (2019) (listing some of Australia's safety regulations prohibiting RPA use over populous areas such as parks).

[30] J.J. Roldán, D. Sanz, J. del Cerro & A. Barrientos, *Lift Failure Detection and Management System for Quadrotors*, 252 ADVANCES INTELLIGENT SYS. & COMPUTING 1,

the drone airborne.[31] Within the motor, a core component is the bearing, a part which allows for a spinning shaft to be connected to the stationary housing via a mechanism with very low friction.[32] However, bearings become fatigued over time, and if this is not addressed by bearing replacement or maintenance, then catastrophic failure can occur with the potential to cause serious damage or harm to persons or property.[33] The available time from initial warning of fatigue to the onset of bearing failure depends on the loading and speed of the motor in operation.[34] One study analyzing 152 RPA incidents from 2006 to 2015 found equipment problems to be responsible for 64% of all RPA accidents and incidents, highlighting the need for reliable equipment and maintenance programs to ensure the drone can safely remain airborne during operation.[35]

Accordingly, to avoid accidents and maintain safe operations, drone companies need to ensure a very low risk of drone motor bearing failure. Currently, this is achieved by providing sufficient redundancy at the expense of weight and cost, and by adhering to a strict and rigorous bearing replacement schedule.[36] However, redundant systems can be uneconomical for many heavy freight transport drones because the weight of the cargo means multiple motors are already required to keep the drone flying. Likewise, bearing replacement schedules are also not an optimal solution as they rely on technical knowledge (making predictions based on previous knowledge and experience) and usage data (making predictions using "historical failure records of comparable equipment without considering component-spe-

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3 (2014), https://www.researchgate.net/profile/Juan-Roldan-Gomez/publication/289979207_Lift_Failure_Detection_and_Management_System_for_Quadrotors/links/576846bc08aef9750b0f9d27/Lift-Failure-Detection-and-Management-System-for-Quadrotors.pdf [https://perma.cc/YW5Q-GFVF].

31 *Id.*

32 *See generally Bearing: Machine Component*, ENCYCLOPAEDIA BRITANNICA, https://www.britannica.com/technology/bearing-machine-component [https://perma.cc/3TV2-HSQW].

33 SKF, BEARING DAMAGE AND FAILURE ANALYSIS 7 (2017), https://www.skf.com/binaries/pub12/Images/0901d1968064c148-Bearing-failures—14219_2-EN_tcm_12-297619.pdf [https://perma.cc/5NM4-GPZG].

34 *Id.*

35 Graham Wild, John Murray & Glenn Baxter, *Exploring Civil Drone Accidents and Incidents to Help Prevent Potential Air Disasters*, 3 AEROSPACE 1, 8 (2016), https://mdpi-res.com/aerospace/aerospace-03-00022/article_deploy/aerospace-03-00022.pdf [https://perma.cc/J466-2C23].

36 *See* Perritt, Jr., *supra* note 27, at 46.

cific differences.").[37] This does not eliminate the likelihood of a bearing fault since contamination; corrosion; incorrect bearing manufacturing, storage, or installation; or excessive loading and vibration can cause early bearing failure before it is scheduled to be replaced.[38] Moreover, preventative maintenance means that bearings are often replaced long before they are close to developing a fault, which is an unnecessary cost and inefficient for operators.[39]

Rather, what is needed is a way to monitor the condition of bearings on a real-time basis.[40] This process, known as condition monitoring, provides the advantage of being able to adequately prepare for bearing maintenance or replacement long before a catastrophic failure.[41] Flagging failures preemptively is also more reliable than conventional preventive or reactive maintenance technologies.[42] Reactive maintenance technologies react to the fault after it occurs and include parachutes, automatic descent software, or back-up redundancy systems, while preventive maintenance technologies include pre-determined replacement schedules.[43] In contrast, health monitoring is mechanism-based and makes predictions based on direct sensing of the critical failure mechanisms of each unique physical model.[44] Existing research has found that "[i]n general, maintenance techniques characterized by real-time monitoring solutions offer more information and a better prediction of the occurring failure and are therefore more favorable."[45] Because studies have shown deficient maintenance to be one of the most common causes of system failure in an RPA,[46] this is an essential area to address.

This discussion demonstrates a clear rationale to consider using drone bearing condition sensing technology as a way to im-

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37 Alberto Martinetti, Erik Jan Schakel & Leo A.M. van Dongen, *Flying Asset: Framework for Developing Scalable Maintenance Program for Unmanned Aircraft Systems* (*UAS*), 24 J. QUALITY MAINT. ENG'G 152, 162 (2018).

38 *See* SKF, *supra* note 33, at 8.

39 *See id.*

40 *See* Martinetti et al., *supra* note 37, at 162.

41 *Id.* at 160.

42 *See generally Reactive Vs. Preventive Vs. Predictive Maintenance*, PROMETHEUS GRP. (June 25, 2020), https://www.prometheusgroup.com/posts/reactive-vs-preventive-vs-predictive-maintenance [https://perma.cc/5VF9-PJCY].

43 *Id.*

44 Martinetti et al., *supra* note 37, at 162.

45 *Id.*

46 *Id.* at 153.

prove the safety of drones. However, while this technology has been investigated from an engineering perspective, the question of whether there is a legal motivation is unexplored.

In this context, this Article aims to address this research gap by investigating the extent to which using drone bearing monitoring technology can mitigate against legal liability, specifically for freight drones. For example, bearing monitoring equipment might be used to warn that a bearing may be about to fail, in which case it may be possible to land the drone before it does any damage,[47] or bearing monitoring equipment may be a source of information about what, if anything, went wrong. Legal liability for drone damage is a significant concern as fleets of delivery drones are already operating today, and with no litigated cases on the matter yet, the consequences of drone negligence, recklessness, or misuse still largely occupy a legal grey area.

Failing to properly fill this gap can hinder the continued innovation of drones and cause market opportunities and other societal benefits to be missed. Conversely, properly bridging the gap will solidify Australia's role as a global leader in the adoption of drones in both an engineering and legal capacity.[48]

III. TECHNICAL AND REGULATORY OVERVIEW OF DRONES

Broadly speaking, there are two types of drones available on the market at varying costs:[49] fixed-wing drones (generally for

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[47] EP Editorial Staff, *Methods for Monitoring Bearing Performance*, EFFICIENT PLANT (Oct. 3, 2013), https://www.efficientplantmag.com/2013/10/methods-for-monitoring-bearing-performance/ [https://perma.cc/FJG4-MLCV].

[48] *See* Submission from Wing Aviation Pty Ltd to Austl. Dep't of Infrastructure, Transp., Reg'l Dev. & Commc'ns, National Aviation Policy Issues Paper on Emerging Aviation Technologies 1 [hereinafter Submission from Wing Aviation], https://www.infrastructure.gov.au/sites/default/files/migrated/aviation/technology/files/submission-34-wing-response-to-national-aviation-policy-issues-paper-on-emerging-aviation-technologies.pdf [https://perma.cc/W3LG-FPNT].

[49] Recreational and hobbyist drones have an average sale price of $2,500, and higher end models for commercial use have an average sale price of $40,000. U.S. CHAMBER INST. FOR LEGAL REFORM, TORTS OF THE FUTURE: ADDRESSING THE LIABILITY AND REGULATORY IMPLICATIONS OF EMERGING TECHNOLOGIES 15 (2017), https://instituteforlegalreform.com/wp-content/uploads/2020/10/Torts_of_the_Future.pdf [https://perma.cc/B4EH-Q7KE]; *see also* FED. AVIATION ADMIN., TC16-0002, FAA AEROSPACE FORECAST: FISCAL YEARS 2016-2036, at 31 (2016), https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/fy2016-36_faa_aerospace_forecast.pdf [https://perma.cc/8RNQ-8SKN].

commercial use, long flight times, or fast-speed missions)[50] and multi-rotor drones (generally for recreational use in locally confined areas, or for more cost-effective missions).[51] These are controlled by drone pilots that can be characterized as adjacent pilots for Visual Line of Sight operations, remote pilots using First Person View, and on-board computer pilots controlling autonomous drones.[52] Based on the size, design, and operation of a drone, the risk of damage has "different consequences and require[s] different mitigations."[53]

A. Freight Drones

Currently, there are four categories of cargo drone uses: first and last mile parcel delivery (for dense urban areas); automation of intralogistics (for factories and warehouses); supply of medical goods (for low-accessibility locations); and transportation of air freight (usually for rural areas).[54] The legal risks of all these activities, as stated above, are mostly concerned with personal injury, death, and damage to property.[55] These are all likely to occur because of a drone falling and doing damage. There is also a possibility that there might be economic losses caused by failures or delays in delivery, but this falls outside the scope of this paper.

Large multinational companies are leading the adoption of freight drones, with many already embarking on various pilot projects.[56] In the United Kingdom, Amazon's Prime Air has been used to deliver packages, relying on drones being "built with multiple redundancies, as well as sophisticated 'sense and

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50 Note that fixed-wing drones can sometimes have a single propeller and motor or a multiple propeller and motor arrangement depending on the design.

51 *See, e.g.*, Michelle Sing Yee Hii, Patrick Courtney & Paul G. Royall, *An Evaluation of the Delivery of Medicines Using Drones*, 3 Drones 1, 16 (2019), https://www.mdpi.com/2504-446X/3/3/52/pdf [https://perma.cc/DR4B-GK2L] (noting the benefit of multi-rotor drones taking off and landing vertically in urban settings).

52 Clarke & Moses, *supra* note 23, at 265.

53 Policy Issues, *supra* note 18, at 25 (alteration in original).

54 Stephan Baur & Manfred Hader, *Cargo Drones: The Future of Parcel Delivery*, Roland Berger (Feb. 19, 2020), https://www.rolandberger.com/en/Insights/Publications/Cargo-drones-The-future-of-parcel-delivery.html [https://perma.cc/TB6B-H5TF].

55 *See Drone Delivery Legal Issues*, HG.org, https://www.hg.org/legal-articles/drone-delivery-legal-issues-53006 [https://perma.cc/N4C3-ZVFJ].

56 *See, e.g.*, Alf Alferez, *Top 10 Commercial Drone Delivery Companies*, eCommerce Next (Aug. 21, 2021), https://www.ecommercenext.org/top-10-commercial-drone-delivery-companies/ [https://perma.cc/PXK4-587U].

avoid' technology" to mitigate dangers.[57] Uber has been testing its Uber Eats drone delivery service in San Diego in the United States (as a precursor to more dense urban environments)[58] alongside Uber's more ambitious Uber Elevate Drone Taxi project in Melbourne.[59] Airbus Helicopters established a memorandum of understanding with the Civil Aviation Authority of Singapore to allow testing of drone delivery on campus at the National University of Singapore.[60] Globally, Wing Aviation Pty. Ltd. (Wing), the drone division of Alphabet (which is Google's parent company), just reached a milestone of 100,000 customer deliveries.[61]

Most of these pilot projects center around first- and last-mile delivery using autonomous drones, which are often linked to e-commerce supply chains.[62] "[T]hese drones carry packages to [and] from a central distribution hub to [and] from a drop-off [or] pick-up location."[63] These hubs can range from a courier distribution center to a retail shop, a food outlet, or a medical center.[64]

In the case of Australia, the wide geographical distances and dispersed populations means that drones could provide real and viable solutions to logistics and transport.[65] Alongside "Austra-

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57 *Amazon Prime Air*, AMAZON, https://www.amazon.com/Amazon-Prime-Air/b?ie=UTF8&node=8037720011 [https://perma.cc/3F3D-2D2S].

58 Peter Holley, *Uber Plans to Start Delivering Fast Food via Drone This Summer*, WASH. POST (June 13, 2019), https://www.washingtonpost.com/technology/2019/06/13/uber-plans-start-delivering-mcdonalds-hamburgers-by-drone-this-summer/ [https://perma.cc/84MB-4D4L].

59 *See* Cara Waters, *Uber Elevate Sale Set to Put Plans for 1000 Melbourne Flying Taxis on Ice*, SYDNEY MORNING HERALD (Dec. 10, 2020, 1:17 PM), https://www.smh.com.au/technology/uber-elevate-s-sale-could-put-plans-for-1000-melbourne-flying-taxis-on-ice-20201210-p56m9z.html [https://perma.cc/B5BA-ZQAG]. Although note that Uber Elevate has since been acquired by Joby Aviation. Eric Allison, *Joby and Uber Elevate*, JOBY AVIATION (July 12, 2021), https://www.jobyaviation.com/blog/joby-uber-elevate/ [https://perma.cc/D9WR-PER8].

60 HODGKINSON & JOHNSTON, *supra* note 12, at 128.

61 *See Logan, Australia: The Drone Delivery Capital of the World*, WING (Aug. 25, 2021), https://blog.wing.com/2021/08/logan-australia-drone-delivery-capital.html [https://perma.cc/GG43-WG3L].

62 *See* DELOITTE ACCESS ECON., *supra* note 3, at 25.

63 See id. (alteration in original).

64 *Id.*

65 POLICY STATEMENT, *supra* note 17, at 19; ALPHABETA, FASTER, GREENER AND LESS EXPENSIVE: THE POTENTIAL IMPACT OF DELIVERY DRONES IN THE AUSTRALIAN CAPITAL TERRITORY 16 (2018), https://wing.com/resource-hub/articles/act-report/ [https://perma.cc/NG95-GL2P].

lia's relatively fast adoption of new technologies," these factors could provide a powerful catalyst for the rapid uptake of delivery drones.[66] The New South Wales (NSW) government observed that automated routine freight delivery and point-to-point transport could well be in use by 2056.[67]

Currently, Australia's Civil Aviation Safety Authority (CASA) has driven most drone adoptions in the country by licensing Wing to operate drone delivery services in North Canberra in the Australian Capital Territory and Logan in Queensland.[68] Consequently, Wing drones are already flying over populations of 10,000 or more residents from morning to early evening on both weekdays and weekends.[69] While these deliveries currently comprise last-mile deliveries,[70] their use could expand across the entire logistics chain as technology advances.

Accompanying this, "Wing is also developing an [uncrewed] traffic management (UTM) platform that will allow [autonomous drones] to navigate around other drones, [crewed] aircraft, and other obstacles like trees, buildings and power lines."[71] This flight path navigation software is interoperable and can automatically "manage different drones from different manufacturers as they conduct deliveries."[72] This software enables fleets of delivery drones to operate on an autonomous or semi-autonomous basis, relying on GPS and on-board computers. A range of other advanced technologies, such as cloud computing, computer visioning, machine learning, and deep learning, allows drones to carry out their missions without human interven-

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[66] *See* DELOITTE ACCESS ECON., *supra* note 3, at 25. The report estimated that by 2040 the number of express parcel deliveries could range from 37 million to 61 million trips, food deliveries from 46 million to 65 million, and pathology deliveries from 8 million to 17 million. *Id.* at 26.

[67] TRANSP. FOR NSW, FUTURE TRANSPORT STRATEGY 2056, at 64 (2018), https://future.transport.nsw.gov.au/sites/default/files/media/documents/2018/Future_Transport_2056_Strategy.pdf [https://perma.cc/CH2P-KSJE].

[68] *Drone Delivery Services*, AUSTL. CIV. AVIATION SAFETY AUTH., https://www.casa.gov.au/drones/industry-initiatives/drone-delivery-services [https://perma.cc/M24B-NJ78] (Feb. 16, 2022). Wing Aviation LLC was also the first company to receive a "Part 135 Single pilot air carrier certificate for drone operations" from the U.S. Federal Aviation Administration in April 2019. *Package Delivery by Drone (Part 135)*, FED. AVIATION ADMIN., https://www.faa.gov/uas/advanced_operations/package_delivery_drone/ [https://perma.cc/3HFC-DF7G] (Oct. 21, 2021, 12:37 PM).

[69] Submission from Wing Aviation, *supra* note 48, at 6.

[70] *See* Oosedo et al., *supra* note 3, at 350–51.

[71] *Wing: Transforming the Way Goods Are Transported*, X (alteration in original), https://x.company/projects/wing/ [https://perma.cc/T2UK-XZ7R].

[72] HODGKINSON & JOHNSTON, *supra* note 12, at 128.

tion.[73] Accordingly, operators at a remote headquarters only oversee rather than "pilot" the drones.

This distinguishes freight drones from most previous iterations of drones, which were predominantly piloted to survey, collect, and gather data.[74] Such a use primarily raised legal issues of surveillance and privacy rights.[75] Conversely, the principal goal of freight drones is transportation of goods,[76] and while the collection of data may be an ancillary utility, it is not the priority or focus of this paper. This is evident from how Wing aircraft's cameras are only still image, greyscale, low-resolution cameras that are for the purpose of providing a backup to its navigation systems.[77] Consequently, the key legal issues that arise from delivery drones are based more on the infringement of tangible rights, such as personal injury and death; property damage; or (possibly) nuisance, e.g., noise or pollution.[78]

The pace of developments in the sector is rapid.[79] However, as with any emerging technology, the challenge for all stakeholders is how to balance innovation with risk.[80] The International Civil Aviation Organization (ICAO), in its Convention on International Civil Aviation, provides that the regulation of pilotless

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73 Lukas Schroth, *Drones and Artificial Intelligence*, DRONE INDUS. INSIGHTS (Aug. 28, 2018), https://droneii.com/drones-and-artificial-intelligence [https://perma.cc/KY38-9NSK].

74 Pam Storr & Christine Storr, *The Rise and Regulation of Drones: Are We Embracing Minority Report or WALL-E?*, *in* ROBOTICS, AI AND THE FUTURE OF LAW 105, 106 (Marcelo Corrales, Mark Fenwick & Nikolaus Forgó eds., 2018).

75 *The Drone Controversy: Are Drones an Invasion of Privacy?*, PSYMBOLIC (Jan. 5, 2022), https://www.psymbolic.com/the-drone-controversy-are-drones-an-invasion-of-privacy/ [https://perma.cc/E2PU-L9QF].

76 *See Privacy Policy*, WING (Nov. 5, 2018), https://wing.com/en_au/privacy-us/ [https://perma.cc/H2YQ-6673] (explaining that data collected is to assist or improve delivery process).

77 *See id.*

78 *Drone Delivery Legal Issues*, *supra* note 55; Michael S. Horikawa & David Wright, *A Drone's Eye View of Rights and Legal Remedies*, PILLSBURY: INTERNET & SOCIAL MEDIA LAW BLOG (July 23, 2020), https://www.internetandtechnologylaw.com/drones-rights-legal-remedies/ [https://perma.cc/97A8-6DRF] (describing briefly how a nuisance suit against a drone would theoretically apply).

79 *The Evolution of Drones, Then and Now*, DRONENERDS, https://enterprise.dronenerds.com/the-evolution-of-drones/ [https://perma.cc/LK9P-NEGZ].

80 *See US Deloitte Drone Services: Government & Commercial Services*, DELOITTE, https://www2.deloitte.com/us/en/pages/public-sector/solutions/drone-services.html [https://perma.cc/9ZYM-HL4C].

aircraft is enacted at the national level.[81] Thus, "in the absence of clear guidelines from international bodies, many domestic jurisdictions . . . draft their own regulations."[82] Many countries exclude small drones below a certain weight from the standard rules that apply to aircraft,[83] while others aim to regulate drones by the same standards as crewed aircraft.[84]

In 2000, Australia became the first country to begin drafting drone regulation laws and has since established itself firmly as a global leader in the space.[85] Rather than developing a new specific regulatory solution, drones were integrated into the existing legal framework, which was developed primarily for airplanes. As a result, the applicable regulations straddle constitutional lines of federal and state powers, creating a complex, overlapping regulatory environment.[86] In Australia, drones are considered "aircraft"[87] and thus fall under the scope of federal aircraft operations and safety laws.[88] Part 101 of the *Civil Avia-*

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[81] Int'l Civ. Aviation Org. [ICAO], *Convention on International Civil Aviation*, at 5, ICAO Doc. 7300/9 (9th ed. 2006), https://www.icao.int/publications/Documents/7300_9ed.pdf [https://perma.cc/V83D-33VR].

[82] HODGKINSON & JOHNSTON, *supra* note 12, at 19.

[83] *Id.* As a guide to sizes, see Des Butler, *Drones and Invasions of Privacy: An International Comparison of Legal Responses*, 42 UNSW L.J. 1039, 1042 (2019). Butler provides "micro RPAs" would be toy drones, "very small RPAs" would be recreational user drones (such as DJI drones), and "large RPAs" would be drones similar in size to Predator drones used by the U.S. military. *Id.* However, regulations of sizes can vary. HODGKINSON & JOHNSTON, *supra* note 12, at 35. For example, Australia's smallest weight category ("micro") is 250 grams or less, while China's smallest weight category (also "micro") is 7 kilograms or less. *Id.*

[84] HODGKINSON & JOHNSTON, *supra* note 12, at 25.

[85] Julie-Anne Tarr, Anthony Tarr, Ron Bartsch & Maurice Thompson, *Drones in Australia – Rapidly Evolving Regulatory and Insurance Challenges*, 30 INS. L.J. 135, 143, 144 n.44 (2019).

[86] Pam Stewart, *Drone Danger: Remedies for Damage by Civilian Remotely Piloted Aircraft to Persons or Property on the Ground in Australia* 28 (July 6, 2017), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2996331 [https://perma.cc/N2EW-2VJ2] (published in Volume 23 of the Torts Law Journal in 2016).

[87] AUSTL. GOV'T CIV. AVIATION SAFETY AUTH., *Drone Rules*, YOUTUBE, at 1:00 (July 30, 2019), https://www.youtube.com/watch?v=-urP2fIJYk8 [https://perma.cc/ZNT6-4GUS] ("Drones may be aircraft, but they can't fly anywhere near major airports."). As per the *Civil Aviation Act 1988*, an aircraft is defined as "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." *Civil Aviation Act 1988* (Cth) s 3 (Austl.). A similar definition appears in the *Air Navigation Act 1920* (Cth) s 3 (Austl.).

[88] *See Civil Aviation Act 1988* (Cth) s 3 (Austl.); *Civil Aviation Safety Regulations 1998 (Cth) reg 21.820 (Austl.); Civil Aviation Regulations 1988* (Cth) reg 2C (Austl.); Air Navigation Act 1920 (Cth) pt 101 (Austl.).

tion Safety Regulations 1998 (CASR)[89] consolidates all the rules applicable to RPAs into one body of legislation. CASA has also issued Part 101 *(Unmanned Aircraft and Rockets) Manual of Standards 2019* (MOS),[90] which sets out further standards in relation to safety and regulatory oversight. The MOS is a Class One document under CASR Part 21, and thus has standing as prima facie evidence in court.[91]

Generally, all drones are subject to standard operating conditions.[92] In Australia, as in most jurisdictions, drones cannot fly higher than 400 feet above ground level without approval from the appropriate regulator,[93] and "high-risk" flights are prohibited without obtaining CASA's grant of approval.[94] Such flights include flying at night, through clouds or fog, over populous areas, near airfields, beyond the pilot's visual line of sight, or within 30 meters of a person who is unrelated to the drone operation.[95]

Following an Australian Senate Inquiry Report into the use and safety of RPA,[96] new legislation mandates compulsory registration and operator accreditation with CASA for all drones except for micro-sized "model aircraft."[97] A micro-sized drone is

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[89] *Civil Aviation Safety Regulations 1998* (Cth) pt. 101 (Austl.).

[90] *See* ADVISORY & DRAFTING BRANCH, LEGAL, INT'L & REGUL. AFFS. DIV., *Part 101 (Unmanned Aircraft and Rockets) Manual of Standards 2019 (as amended)*, CIV. AVIATION SAFETY AUTH. (2020).

[91] RONALD I C BARTSCH, AVIATION LAW IN AUSTRALIA 475 (4th ed. 2013).

[92] *Drone Safety Rules*, CIV. AVIATION SAFETY AUTH., https://www.casa.gov.au/drones/drone-rules/drone-safety-rules [https://perma.cc/23ZC-PFR3] (Mar. 21, 2022).

[93] HODGKINSON & JOHNSTON, *supra* note 12, at 35; *Civil Aviation Safety Regulations 1998* (Cth) sub-reg 101.085(1) (Austl.); 14 C.F.R. § 107.51 (2021).

[94] *See, e.g.*, *Civil Aviation Safety Regulations 1998* (Cth) reg 101.280 (Austl.).

[95] *Id.* regs 101.095, 101.245, 101.280; *Drone Safety Rules*, *supra* note 92. A "populous area" is defined in the regulations as an area that "has a sufficient density of population for some aspect of the operation, or some event that might happen during the operation (in particular, a fault in, or failure of, the aircraft . . .) to pose an unreasonable risk to the life, safety or property of somebody who is in the area but is not connected with the operation." *Civil Aviation Safety Regulations 1998* (Cth) reg 101.025 (Austl.).

[96] AUSTL. SENATE INQUIRY, *supra* note 19, at 4 para. 1.12.

[97] *See* Explanatory Statement, Deputy Prime Minister & Minister of Infrastructure, Transp. & Reg'l Dev., Civil Aviation Safety Amendment (Remotely Piloted Aircraft and Model Aircraft – Registration and Accreditation) Regulations (No. 2) 2019 (Cth) Attachment A: Statement of Compatibility with Human Rights (Austl.). However, non-excepted micro-sized model aircraft are subject to a registration requirement. *Id.* Model aircraft above 250 grams are also excepted if they are operated indoors or at CASA-approved Model Aircraft flying fields. *Id.*; *Register Your Drone*, CIV. AVIATION SAFETY AUTH., https://www.casa.gov.au/drones/re-

one weighing no more than 250 grams.[98] Under CASR, model aircraft are excluded from the definition of an RPA.[99] A model aircraft is defined as an aircraft used for the purpose of sport or recreation weighing less than 150 kg; or an aircraft used for educational, training, or research purposes weighing less than 7 kg.[100] Any drone operated for a purpose other than sport and recreation is defined as an RPA.[101] Thus, the only exclusions from registration are micro-toy drones or entry-level hobbyist drones, such as the 249 gram Mavic Mini, which are specifically designed to fall outside regulations (so long as their operation remains exclusively for sport or recreation).[102]

Accordingly, beginning January 28, 2021,[103] all drones classified as RPAs—regardless of size—require registration[104] and accreditation with CASA.[105] Then, depending on the extent of the commercial use,[106] applying for a Remote Pilot License (RePL)[107] or Remote Operator Certificate (ReOC)[108] may be re-

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gistration-and-flight-authorisations/register-your-drone [https://perma.cc/FM3B-2W24] (Dec. 23, 2021).

98 *Civil Aviation Safety Regulations 1998* (Cth) reg 101.022 (Austl.).

99 *Id.* reg 101.021; *Civil Aviation Act 1988* (Cth) s 4 (Austl.).

100 While the term "model aircraft" is not defined in either the *Damage by Aircraft Act 1999* (Cth) s 4 (Austl.) or the *Civil Aviation Act 1988* (Cth) s 3 (Austl.), *Civil Aviation Safety Regulations 1998* (Cth) reg 101.023 (Austl.) provides the definition. However, note that "giant model aircraft" (i.e., aircraft with a take-off mass of 25–150 kg) require operational approval and do not fit within this definition. *See id.* regs 101.380, 101.405.

101 *Civil Aviation Safety Regulations 1998* (Cth) regs 101.021, 101.023 (Austl.).

102 *See* DJI Support, *DJI Mavic Mini FAQ: Answer Your Questions*, DJI GUIDES (Aug. 19, 2020), https://store.dji.com/guides/mavic-mini-faq-everything-you-need-to-know/ [https://perma.cc/Z7N8-JP4P] ("Weighing under 250 grams, Mavic Mini is almost as light as the average smartphone. This makes it exceptionally portable and places it in the lowest and safest weight class of drones, which in many countries may exempt it from certain regulations.").

103 *See CASA 44/20 – Remotely Piloted Aircraft – RPA Application Day Determination 2020* (Cth) s 3 (Austl.).

104 *See Civil Aviation Safety Regulations 1998* (Cth) div 47.c.2 (Austl.). Previously, micro RPA were excluded, even if their purpose was for hire and reward. *See id.* reg. 101.237; Norton White, *Drone Regulation in Australia*, LEXOLOGY (Dec. 10, 2019), https://www.lexology.com/library/detail.aspx?g=9c52371e-5bf2-4ef7-a922-ffd777689918 [https://perma.cc/GF3B-AW5B].

105 *See Civil Aviation Safety Regulations 1998* (Cth) divs 101.F.3–101.F.4 (Austl.).

106 Certain "excluded RPA" do not require a remote pilot license, such as those used for the benefit of the RPA owner's land for activities such as aerial spotting, land surveying, agricultural operations, infrastructure inspections, or carrying cargo. *Id.* reg 101.237. Micro RPAs are also excluded. *Id.* reg 101.235(3).

107 The RePL is a legal document that permits an individual to operate an RPA within the categories shown on the license. *Remote Pilot Licence,* CIV. AVIATION

quired. Flying an unregistered drone,[109] flying without an operator accreditation, or flying without a remote pilot license for business use[110] is a strict liability offense and carries penalties of up to fifty units.[111]

Freight RPAs are regulated by the same regime that applies to commercial RPA operators.[112] Any legal entity[113] wishing to carry out RPA operations in Australia, either commercially or for the purpose of research and development (R&D), must obtain a ReOC.[114]

To satisfy a ReOC, the RPA operator must have a chief remote pilot[115] who holds a remote pilot license and who is competent to carry out those duties and perform the necessary functions.[116] For example, in the case of a freight drone, the ReOC needs a description of the cargo or payloads and the requirements for special handling.[117] The chief remote pilot must also either maintain a position as maintenance controller or arrange a com-

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SAFETY AUTH., https://www.casa.gov.au/drones/get-your-operator-credentials/remote-pilot-licence [https://perma.cc/SN3B-W2R5] (Dec. 23, 2021).

108 The ReOC permits a business to operate commercial or R&D operations in Australia. *Remotely Piloted Aircraft Operator's Certificate*, CIV. AVIATION SAFETY AUTH., https://www.casa.gov.au/drones/get-your-operator-credentials/remotely-piloted-aircraft-operators-certificate [https://perma.cc/NZ7C-EFAE] (Feb. 21, 2022). Much like a license, the ReOC will provide information on what categories and types of RPA may be operated as well as the privileges and limitations of the approved operations. *See id.* "A ReOC is required for more complex commercial RPA activities, such as flying at night or over people," for a person to obtain a ReOC, they must complete training through a certified training provider. CIV. AVIATION SAFETY AUTH., CASR PART 101: MICRO AND EXCLUDED REMOTELY PILOTED AIRCRAFT OPERATIONS 4 (2020), https://www.casa.gov.au/sites/default/files/2021-08/part-101-micro-excluded-rpa-operations-plain-english-guide.pdf [https://perma.cc/P8JS-58GG].

109 *Civil Aviation Safety Regulations 1998* (Cth) sub-reg 47.015(1) (Austl.) requires aircraft to be registered unless they are exempt.

110 *Id.* sub-reg 101.374B(1).

111 *Id.* As of the time of writing, one penalty unit is 222 AUD under the *Crimes Act 1914* (Cth) s 4AA (Austl.).

112 White, *supra* note 104.

113 A ReOC holder "must be a natural person or have legal personality (capable of enjoying and being subject to legal rights and duties)." CIV. AVIATION SAFETY AUTH., FORM 101-06: INSTRUMENT OF DELEGATION APPLICATION FOR RPA OPERATOR'S CERTIFICATE, at ii (2016), http://www.unmannedapprovals.com.au/wp-content/uploads/2016/11/Form101-06.pdf [https://perma.cc/TG9E-FK2F].

114 *See Civil Aviation Safety Regulations 1998* (Cth) reg 101.340 (Austl.).

115 *Id.* sub-reg 101.340(1)(a).

116 *Id.* sub-reg 101.340(1)(b).

117 *See* Part 101 *(Unmanned Aircraft and Rockets) Manual of Standards 2019 (as amended)* (Cth) sub-div 10.03(1)(b)(v) (Austl.).

petent person to do so.[118] Failure to comply is a strict liability offense with a penalty of fifty penalty units.[119]

A maintenance controller has a duty to ensure that maintenance is completed to an adequate standard.[120] Generally, this includes "maintaining a record of the serviceability . . . of the operator's RPA systems[,] ensuring that each item of equipment essential to the operation of the operator's RPA is serviceable . . . [and] investigating all defects in the operator's RPA systems."[121] Part of this includes keeping a technical log, which outlines information relating to the continuing airworthiness of the RPAs, such as its total flight time; maintenance schedule; dates for the next maintenance action; documented practices and procedure of maintenance; the results of any rectification of defective equipment; and descriptions of pieces of unserviceable parts.[122]

Additionally, a job-safety assessment is required for certain RPA operations, almost certainly including freight drones.[123] A job-safety assessment is completed in accordance with the ReOC's procedures and involves identifying safety risks and formulating risk mitigation measures and risk management plans.[124] These include factors such as the weather, danger to the public, obstructions, or possible interference from power-

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118 *Civil Aviation Safety Regulations 1998* (Cth) sub-reg 101.340(c) (Austl.).

119 *Id.* reg 101.370.

120 *Id.* sub-reg 101.340(1)(c)(i) (alteration in original). The *Civil Aviation Act* defines "maintenance" as: "any task required to ensure, or that could affect, the continuing airworthiness of an aircraft or aeronautical product, including any one or combination of overhaul, repair, inspection, replacement of an aeronautical product, modification or defect rectification." *Civil Aviation Act 1988* (Cth) s 3 (Austl.).

121 CIV. AVIATION SAFETY AUTH., ADVISORY CIRCULAR AC 101-05: FUNCTIONS AND DUTIES OF RPAS MAINTENANCE CONTROLLERS (2016) (alteration in original), https://www.casa.gov.au/sites/default/files/2021-08/advisory-circular-101-05-functions-duties-rpas-maintenance-controllers.pdf [https://perma.cc/6MCL-U8PE].

122 *See* Part 101 *(Unmanned Aircraft and Rockets) Manual of Standards 2019 (as amended)* (Cth) sub-reg 10.07(d) (Austl.).

123 *See* White, *supra* note 104.

124 *Id.*

lines or antennas.[125] Further rules apply to large RPAs[126] and autonomous RPAs.[127]

Obviously, a reliable drone bearing monitoring system that demonstrates the airworthiness of a drone will greatly assist an operator in both meeting and proving the satisfaction of many of these requirements.

Regarding delivery drones specifically, current regulations allow RPAs to deliver "just-in-time" supplies to customers living within a ten-kilometer radius from a base station.[128] Items available for delivery include food and drinks, medicine, small items of hardware, and recreational supplies.[129] Wing has been allowed to operate in this capacity after a rigorous safety screening and submission of applications to operate beyond visual line-of-sight.[130]

However, CASA's approval of a drone operation does not automatically establish immunity should an accident or regulatory breach occur.[131] It will still be an offense to operate an RPA in a way that creates a hazard to other aircraft, people, or property

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125 *See Hazard Identification and Management in Aviation*, CIV. AVIATION SAFETY AUTH., https://www.casa.gov.au/operations-safety-and-travel/safety-advice/hazard-identification-and-management-aviation [https://perma.cc/76HQ-N498] (Dec. 23, 2021).

126 *Civil Aviation Safety Regulations 1998* (Cth) reg 101.260 (Austl.) requires that any person who carries out maintenance on a large RPA comply with any directions given in writing by CASA.

127 *Id.* reg 101.097 requires approval from CASA before an autonomous aircraft is launched.

128 *Drone Delivery Services*, *supra* note 68.

129 *Id.*

130 *Id.* To operate beyond or extended visual line-of-sight class 2 operations in Australia, the remote pilot, or supervising remote pilot of the operator, must meet the requirements as defined in CASA Exemption EX46/21. *See Civil Aviation Safety Regulations 1998* (Cth) sub-reg 101.300(4) (Austl.). These include holding certain licenses, passing the Australian Instrument Rating Exam (IREX), and passing other CASA-approved examinations. *See id.* Operators are also generally required to conduct a Specific Operational Risk Assessment (SORA) and participate in a workshop with CASA. *JARUS Guidelines on Specific Operations Risk Assessment (SORA)*, JOINT AUTHS. FOR RULEMAKING OF UNMANNED SYS., JAR-DEL-WG6-D.04, at 11 (2d. ed. 2019), https://wpo-altertechnology.com/wp-content/uploads/2017/11/jar_doc_06_jarus_sora_v1.0.pdf [https://perma.cc/K3DP-F4CB]. The SORA is an operational risk assessment developed by the Joint Authorities for Rulemaking in Unmanned Systems (JARUS). *Id.*

131 Kate Tilley, *Drones – Friend or Foe for Underwriters?*, RESOLVE (Mar. 30, 2016), *republished in* MERIDIAN LAWYERS: INSIGHTS, https://www.meridianlawyers.com.au/insights/drones-friend-foe-underwriters/ [https://perma.cc/9FUY-HCZ2].

with a penalty up to fifty units for contravention.[132] Further, the *Civil Aviation Act 1988*, *the Aviation Transport Security Act 2004*, and aviation security regulations consider interference with the safe conduct of air transport and reckless flying as criminal offenses, which can result in imprisonment.[133] An operator who negligently or carelessly fails to conduct the required maintenance on their drone motor bearing will be exposed to liability under these Acts. The Australian government is developing a new enforcement framework to allow state and territory police to issue infringement notices and enforce minor breaches of drone regulations, while prosecution of serious offenses remains under existing legislation.[134]

However, these offenses are only penal in nature, meaning that the parties who suffer harm from their violation have no entitlement to compensation, and they will instead need to turn to other legal avenues such as statutes or common law.[135] Additionally, it will be up to CASA to investigate any breaches of these regulations, subject to its own resources and limitations.

Notwithstanding these existing regulations, there are also several areas where future regulation and liability are likely to emerge. This Article now addresses four developing areas: airworthiness, noise, insurance, and cybersecurity.

B. Airworthiness

CASA has yet to implement a comprehensive set of airworthiness regulations for the drone industry. Currently, only large RPAs weighing more than 150 kilograms are required to obtain a certificate of airworthiness.[136] Otherwise, the only requirements are contained within the airworthiness standards of an operator's technical logs[137] and the general understanding of airworthiness as an aeronautical knowledge unit for RePL training courses.[138] There will be a variety of different sizes of delivery drones, depending on the flight distance and weight of the

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132 *Civil Aviation Safety Regulations 1998* (Cth) sub-reg 101.055(1) (Austl.).

133 White, *supra* note 104.

134 Policy Issues, *supra* note 18, at 27.

135 *See* Hawke v. Waterloo-Wellington Flying Club Ltd. et al. (1971), 22 D.L.R. 3d 266, 272–73 (Can. Ont. Co. Ct. J.) (discussing and finding negligence for failure to keep maintenance log books).

136 *Civil Aviation Safety Regulations 1998* (Cth) regs 101.046, 101.255 (Austl.).

137 Part 101 *(Unmanned Aircraft and Rockets) Manual of Standards 2019 (as amended)* (Cth) ss 10.07(1)(d), 10.12(2)(b) (Austl.).

138 *Id.* sch 4 appendix 1 unit 6 (Austl.).

payload. Lighter drones (specializing in last-mile delivery) are expected to carry an estimated 2.5 kilogram payload with round-trip distances of twenty kilometers by 2030.[139] Currently, Wing's delivery drones are designed to weigh 4.8 kilograms and deliver small packages that weigh approximately 1.5 kilograms or less.[140] Larger delivery drones may have a maximum payload of 15 kilograms, and the craft itself would probably weigh 5–20 kilograms.[141] For example, Swoop Aero drones can transport up to five kilograms of supplies across geographical ranges up to 130 kilometers and have a maximum take-off weight of eighteen kilograms.[142] These significant variations in size pose a challenge for regulators, compelling some—such as the U.S. National Transportation Safety Board—to move criterion from weight-based thresholds to holding airworthiness certificates.[143]

The Australian Senate Inquiry recommended the development of clearly defined airworthiness standards with mandated fail-safe functions.[144] It has been argued that a set of standards would "clarify expectations about the continuum of specification, design, construction, operation and maintenance of RPAs" and assist in regulating imported and domestically manufactured RPA products.[145] One submission to the Inquiry commented, "RPA hardware has not undergone significant testing and malfunctions are common. Mean time between failure of the electric motors is not known and software is potentially 'open-source' with many 'bugs.'"[146] Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) sub-

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139 AlphaBeta, *supra* note 65, at 11.

140 *Drone Delivery Under Google's Wing*, Osinto (Jan. 24, 2020), https://www.osinto.com/post/drone-delivery-under-googles-wing [https://perma.cc/M9X2-HMTF]. Similarly, Amazon Prime Air delivery drones can deliver packages up to 2.26 kilograms (five pounds). Elyse Betters, *How Does Amazon Prime Air Work and Where Is Drone Delivery Available?*, Pocket-lint (Dec. 16, 2016), https://www.pocket-lint.com/drones/news/amazon/139746-how-does-amazon-prime-air-work-and-where-is-drone-delivery-available [https://perma.cc/C3M8-YEDL].

141 *See, e.g.*, *Hercules 20 Heavy Lift Drone*, Drone Volt, https://www.dronevolt.com/en/expert-solutions/hercules-20/ [https://perma.cc/P5F4-4G3Y].

142 *Say Hello to Kite*, Swoop Aero, https://swoop.aero/kite [https://perma.cc/4KLG-AW2C]; Nadine Cranenburgh, *Drones Deliver Vaccines to Remote Areas of the South Pacific in World-First Trial*, Create (Dec. 13, 2018), https://createdigital.org.au/drone-delivery-vaccines-world-first [https://perma.cc/JFB7-GS3T].

143 Amendment to the Definition of Unmanned Aircraft Accident, 86 Fed. Reg. 27,550, 27,551 (proposed May 21, 2021) (to be codified at 49 C.F.R. pt. 830).

144 Austl. Senate Inquiry, *supra* note 19, at 108 para. 8.37.

145 *Id.* at 83 para. 6.29 (citation omitted).

146 *Id.* at 84 para. 6.30 (citation omitted).

mitted that "[p]resently the risk mitigation relies on operational safety controls such as operator and crew licencing together with operational limitations."[147] These conclusions align with current research in the engineering field. For example, Martinetti, Schakel, and van Dongen have pointed out that the maintenance program of RPA companies is mainly based on internal knowledge, meaning that quality depends on the competence and experience of the mechanics.[148] In a nascent market, drone startup companies and divisions are operating with limited resources, and because legislation on airworthiness is still in development, designing systems with absolute safety takes less of a priority than profit-generating functions.[149] This presents a danger because maintenance errors can go undetected as latent conditions for years.[150]

A drone bearing condition monitoring system would mitigate many of these concerns, and if proven to be reliable, could be a strong defense in the future of any legal liability arising from a regime based on airworthiness. However, the probability of missed detections or false positive (false alarm) results with the condition monitoring system needs to be considered here. Note that a missed detection means that a fault occurs and goes undetected by the condition monitoring system; whereas, a false positive means that the system is healthy, but the condition monitoring system incorrectly diagnoses a fault.[151] False positives can lead to inefficiencies, increased costs, or financial losses, while missed detections can lead to incidents and hence possible liability.[152] The probabilities of detecting a fault and avoiding false alarms are always traded against each other.[153] The legal implication of this trade-off will mean, depending on the cause of action, that foreseeability and a breakdown of the monitoring system will need to be taken into account. The existence of this trade-off suggests that drone bearing condition

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[147] *Id.* at 84–85 para. 6.33 (citation omitted).

[148] Martinetti et al., *supra* note 37, at 153.

[149] *See id.*

[150] *See id.*

[151] COMPUT. SEC. RES. CTR., *Glossary: False Positive*, NAT'L INST. STANDARDS & TECH. https://csrc.nist.gov/glossary/term/false_positive [https://perma.cc/WKK6-K4Q8].

[152] *See* Bin Zhang, Chris Sconyers, Carl Byington, Romano Patrick, Marcos E. Orchard & George Vachtsevanos, *A Probabilistic Fault Detection Approach: Application to Bearing Fault Detection*, 58 IEEE TRANSACTIONS ON INDUS. ELECS. 2011, 2011 (2011).

[153] *See id.* at 2012.

monitoring may need to be part of a holistic bearing maintenance program to ensure that the safest, most cost-effective, and least legally liable solution is achieved.

Currently, both the Department of Infrastructure, Transport, Regional Development and Communications[154] and CASA are "investigating the merits of adopting an appropriate airworthiness framework model," including potentially mirroring the frameworks of other aviation authorities.[155]

C. Noise

While no drone-specific regulations on noise currently exist, the *Air Navigation (Aircraft Noise) Regulations 2018* apply to commercial and recreational drone operations, and CASA will likely undertake an assessment of noise before approving operations.[156] Approval may be revoked if a condition of approval is breached or use of the aircraft will likely have a significant noise impact on the public.[157]

In NSW, drones are also captured under the *Protection of the Environment Operations Act 1997*.[158] The definition of aircraft includes a remotely piloted aircraft, an uncrewed aircraft system, or a drone.[159] Persons who find the sound of a drone offensive can seek a noise abatement order from the court, which operates like an injunction on the drone operator to stop the noise.[160]

Worn or damaged bearings usually have identifiable indicators such as vibration (which may generate audible noise) and increased friction heat (which may generate higher than ex-

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154 Policy Statement, *supra* note 17, at 17.

155 Austl. Senate Inquiry, *supra* note 19, para. 6.34 at 85 (citing Civil Aviation Safety Authority, *Submission 17*, at 10–11 (Austl.)); *see Discussion Paper: UAS Airworthiness Framework*, Civ. Aviation Safety Auth. para. 4.9 (2016), https://www.coaxhelicopters.com/wp-content/uploads/2019/01/CASA-UAS-Airworthiness-Discussion-Paper-UAS-Airworthiness-Framework.pdf [https://perma.cc/4TAK-8JBV] (discussing how CASA's paper looks at the JARUS and European Aviation Safety Agency (EASA) frameworks).

156 *Air Navigation (Aircraft Noise) Regulations 2018* (Cth) reg 17 (Austl.); *Drone Delivery Operations–Australia*, Dep't Infrastructure, Transp., Reg'l Dev. & Commc'ns, https://www.infrastructure.gov.au/infrastructure-transport-vehicles/aviation/emerging-aviation-technologies/drone-delivery-operations-australia [https://perma.cc/7CEF-DSLB].

157 *Air Navigation (Aircraft Noise) Regulations 2018* (Cth) reg 17 (Austl.).

158 *Protection of the Environment Operations Act 1997* (NSW) (Austl.).

159 *Id.* at div. 4.

160 *Id.* at divs. 2, 3.

pected bearing temperatures).[161] Monitoring for the first signs of wear can minimize noise and ensure that noise regulations are complied with, especially for larger delivery RPAs, which may be significantly louder or generate higher pitch buzzing sounds due to the high-speed small rotors in their propellers.[162]

The Australian government is developing the National Drone Detection Network during 2021 and 2022 with the aim of starting operations in 2023.[163] Included is an outcome-based noise framework, which will have processes for measuring noise output, modelling of noise impacts (including cumulative impacts) at ground level, and imposing agreed noise-threshold settings to reflect noise sensitivity of particular communities.[164] It is likely that further regulations will follow after this is implemented and more data is available.

D. INSURANCE

Many countries, including Canada, China, Austria, Belgium, Cyprus, Germany, and Italy, require mandatory insurance.[165] The type of coverage that is required varies by jurisdiction, from insurance that covers all aspects of an operation to only third-party insurance.[166] In Canada, for example, insurance is required with respect to "every incident related to the operation of the aircraft,"[167] while in the European Union, commercial drone operators are required to have third-party liability insurance.[168] Australia (alongside the United States, Indonesia, and Brazil) does not require mandatory insurance, although CASA does strongly advise that RPA operators discuss with insurers the potential liability to third parties and consider taking out insurance.[169]

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161 S. J. Lacey, *Using Vibration Analysis to Detect Early Failure of Bearings*, AGG-NET, https://www.agg-net.com/resources/articles/maintenance-repair/using-vibration-analysis-to-detect-early-failure-of-bearings [https://perma.cc/W63N-TQA5].

162 Garth Paine, *Drones to Deliver Incessant Buzzing Noise, and Packages*, CONVERSATION (May 3, 2019, 6:42 AM), https://theconversation.com/drones-to-deliver-incessant-buzzing-noise-and-packages-116257 [https://perma.cc/WB5L-L6HK].

163 POLICY STATEMENT, *supra* note 17, at 8.

164 *Id.* at 22.

165 HODGKINSON & JOHNSTON, *supra* note 12, at 36.

166 *Id.*

167 Canadian Aviation Regulations, SOR/96-433 (Can.) (Regulation 606.02(2)).

168 *See* Council Regulation 785/2004 of Apr. 21, 2004, Insurance Requirements for Air Carriers and Aircraft Operators, 2004 O.J. (L 138) 1, 11.

169 CIV. AVIATION SAFETY AUTH., REMOTELY PILOTED AIRCRAFT SYSTEMS - LICENSING AND OPERATIONS AC 101-01, 35 (2019), https://www.casa.gov.au/remotely-

CASA can also "impose a condition on a licensed commercial drone operator to obtain insurance as part of that operator's risk management procedures," such as when an operator wants to operate commercially at night.[170] RPA operators may also be "expected to have public liability coverage as part of state and territory business obligations."[171] However, where an operator uses an unregistered drone, "[p]ublic liability insurance could be voided as operating an unregistered drone [is] an illegal activity."[172]

While no standard form of drone insurance exists, coverage for drone-related losses can be found in traditional policies covering first-party loss, such as damage to the drone aircraft itself, or coverage for third-party claims for damage caused by the drone.[173] It has also been noted that there is an increasing number of insurers offering specialized drone insurance; for example, Flock launched an app for "pay-as-you-fly" drone insurance in Europe.[174]

A drone bearing monitoring device with data-recording capabilities would provide invaluable information to insurance companies about the technical durability of the drone and would assist in determining whether fault should be attributed to a mechanical failure or an operator. This could operate analogously to a plane's flight recorder as a sort of "black box," which are often used as important evidence in court proceedings.[175]

Academics have criticized the fact that current regulations keep insurance optional, especially in the commercial operating

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piloted-aircraft-systems-licensing-and-operations [https://perma.cc/DYS4-VUKP].

[170] Tarr et al., *supra* note 85, at 151.

[171] *Id.*

[172] *Commercial Drone Registration Warning*, AUSTL. CIV. AVIATION SAFETY AUTH. (Jan. 27, 2021) (alteration in original), https://www.casa.gov.au/about-us/content-search/news-media-releases-speeches/commercial-drone-registration-warning [https://perma.cc/6K7K-PPE7].

[173] Michael S. Levine & Jorge R. Aviles, *As Amazon's and Walmart's Drones Take to the Skies, It Is Important for Commercial Policyholders to Have a Strategy to Protect Against Drone-Related Risks and to Maximize Their Recovery in the Event of a Loss*, LEXOLOGY (Sept. 11, 2020), https://www.lexology.com/library/detail.aspx?g=ada9eb20-ef4e-4b1a-9891-0ebf730cea6c [https://perma.cc/7J7T-VVAE].

[174] Tarr et al., *supra* note 85, at 151.

[175] P de Jersey, C.J., Supreme Court of Queensland, David Boughen Memorial Address at the Aviation Law Association of Australia and New Zealand Conference: The Disclosure in Evidence of Black Box Recordings (Oct. 18, 1999). *See generally* Carol A. Roberts, *The Status of Flight Recorders in Modern Aircraft*, 43 J. AIR L. & COM. 271, 272 (1977).

context.[176] As the sector develops, further regulation creating mandatory insurance may appear on the horizon, especially for commercial industries such as freight or transport.

E. Cybersecurity

Drones are also subject to communication and media regulatory frameworks.[177] Wireless communication links used by drones rely on access to the radiofrequency spectrum to provide the command-and-control functions (e.g., telemetry, radar, and navigation) and payload communications (e.g., high-resolution video).[178] Communication spectrum management legislation regulates wireless frequencies and imposes manufacturing standards.[179]

Drones use software and continuous streams of data to determine their location and behavior. However, these may not be encrypted, leading to drones becoming increasingly favored as a target for hackers. Because of their larger size and weight, freight drones may be a more attractive target than recreational or survey drones for malicious purposes.

For example, in the Geraldton Endure Batavia Triathlon in Western Australia in April 2014, a triathlete was reported to have sustained head lacerations after being struck in the head by a drone that had been filming the race and had fallen from the sky.[180] The owner of the drone did not have a commercial license, and the chief pilot was his twenty-year-old daughter.[181]

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176 *See, e.g.*, Tarr et al., *supra* note 85, at 156; Stewart, *supra* note 86, at 27.

177 *See generally Telecommunications Act 1997* (Cth) (Austl.); *Telecommunications (Consumer Protection and Service Standards) Act 1999* (Cth) (Austl.); *Radiocommunications Act 1992* (Cth) (Austl.).

178 Nozhan Hosseini, Hosseinali Jamal, Jamal Haque, Thomas Magesacher & David W. Matolak, *UAV Command and Control, Navigation and Surveillance: A Review of Potential 5G and Satellite Systems*, 2019 IEEE Aerospace Conf. 1, 1 (2019).

179 *See, e.g.*, *Radiocommunications Labelling (Electromagnetic Compatibility) Notice 2008* pt. 2(2.1) (Austl.); *Radiocommunications (Electromagnetic Compatibility) Standard 2008* para. 5 (Austl.); *Radiocommunications (Compliance Labelling – Devices) Notice 2014* pt. 1(5) (Austl.). There are also State-based regulations. *See, e.g.*, *Electricity Safety Act 1998* (Vic) (Austl.).

180 Michael Safi, *Air Safety Investigation into Drone Incident with Triathlete*, Guardian (Apr. 8, 2014), https://www.theguardian.com/world/2014/apr/08/air-safety-triathlete-struck-drone [https://perma.cc/KW5B-YRNC].

181 *Geraldton Businessman Whose Drone Fell from Sky, Injuring Triathlete, Mocks Crash Probe on Social Media*, Courier Mail (Nov. 7, 2014, 5:28 PM), https://www.couriermail.com.au/news/national/geraldton-businessman-whose-drone-fell-from-sky-injuring-triathlete-mocks-crash-probe-on-social-media/news-story/186bac1f1ec1445bc64e867828c09a25 [https://perma.cc/EE3X-S3B9].

The owner's statement that the drone was hacked fueled initial media speculation about what went wrong, but the owner later retracted his claim.[182]

The matter was referred by CASA to the Commonwealth Department of Public Prosecutions (CDPP), which found "[t]he evidence indicated that the cause of the incident was not the actions of the operator but rather radio interference to the UAV [Unmanned Aerial Vehicle] caused by the event's timing device."[183] The CDPP did not proceed with prosecution after taking into account all of the circumstances, including the young age of the operator.[184] The matter was returned to CASA, and the owner was only fined $1,700 for flying the drone within thirty meters of people.[185]

This event demonstrates the potential harm to people where drones are operated in populated areas. While the cause of the crash was inconclusive in this case, if the case did proceed to litigation, and if a motor and motor bearing monitoring system had been installed, the device could have provided insight as to whether the fault was due to issues with motor operation or whether the fault was present in another drone sub-system such as the flight control system or flight control sensors.

Lawyers have commented that an increase in government regulation of cybersecurity measures for drones is imminent.[186] Indeed, the Australian government is developing security regulations and is considering the future inclusion of "cyberworthiness" standards over RPAs.[187]

While many of the above regulations are currently undeveloped and only broadly applicable to the failure of a freight drone's bearing motor, there are nonetheless specific laws that

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182 *See* Ben Grubb, *'River of Blood' After Drone 'Hits' Australian Athlete*, SYDNEY MORNING HERALD, https://www.smh.com.au/technology/river-of-blood-after-drone-hits-australian-athlete-20140407-zqruh.html [https://perma.cc/Q67Y-A994] (Apr. 7, 2014, 7:08 PM); Safi, *supra* note 180.

183 Sarah Taillier, *Drone Operator Fined After UAV Crashed into Geraldton Triathlete*, ABC NEWS (alteration in original) https://www.abc.net.au/news/2014-11-13/drone-operator-at-geraldton-marathon-fined/5887196 [https://perma.cc/A5AM-NKX8] (Nov. 12, 2014, 6:25 PM).

184 *Cf.* COURIER MAIL, *supra* note 181.

185 Taillier, *supra* note 183.

186 *See* Darryl Smith & Marcus O'Brien, *Cyber: A View from Above*, LEXOLOGY (Dec. 13, 2017), https://www.lexology.com/library/detail.aspx?g=78b0bf74-a6d8-4436-acdb-471d70ad7e5c [https://perma.cc/LZP9-LUJU].

187 POLICY STATEMENT, *supra* note 17, at 21.

can turn the case into a litigated matter. This is discussed in the following part.

IV. LEGAL LIABILITY CREATED BY BEARING FAILURE

While Australia's drone regulations are advanced compared to the rest of the world,[188] there has yet to be any reported decisions of civil or criminal actions in court related to drones. Most documented injuries have only been minor in nature.[189]

However, the relative lack of incidents does not imply the potential does not exist. CASA has commissioned reports to this effect, investigating the possibility for injury to persons on the ground from drones.[190] Likewise, academics have pointed out that the possibility for damage to persons and property on the ground is apparent, "whether the cause be illegal or irresponsible use, system failure, equipment malfunction, or human error."[191]

Liability for personal injuries caused by drone bearing failures may arise in a number of legal frameworks. If drones are certified as aircraft (as freight drones would be), then liability may arise under the various statutes which provide for damage by aircraft.[192] Most of these statutes in Australia will apply strict liability—that is, if the damage is caused by the aircraft, liability will be found regardless of the defendant's lack of fault, intent, recklessness, or negligence.[193]

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[188] *See* THERESE JONES, INTERNATIONAL COMMERCIAL DRONE REGULATION AND DRONE DELIVERY SERVICES 20 (2017), https://www.rand.org/content/dam/rand/pubs/research_reports/RR1700/RR1718z3/RAND_RR1718z3.pdf [https://perma.cc/ZQK9-GMM6].

[189] Serap Gorucu & Yiannis Ampatzidis, *Drone Injuries and Safety Recommendations: AE560/AE560*, 2021 DEP'T AGRIC. & BIOLOGICAL ENG'G IFAS EXTENSION U. FLA. 1, 2 (2021), https://journals.flvc.org/edis/article/view/128455/131011 [https://perma.cc/MJS6-SE2F].

[190] *See, e.g.*, *Human Injury Model for Small Unmanned Aircraft Impacts*, AUSTL. CIV. AVIATION SAFETY AUTH. & MONASH UNIV. 2 (2013), https://www.casa.gov.au/sites/default/files/2021-12/human-injury-model-small-unmanned-aircraft-impacts.pdf [https://perma.cc/AVV4-JDYX].

[191] Stewart, *supra* note 86, at 3. For similar statements, see Perritt, Jr., *supra* note 27, at 64; Vivek Sehrawat, *Liability Issue of Domestic Drones*, 35 SANTA CLARA HIGH TECH. L.J. 110, 117–19 (2018).

[192] *Damage by Aircraft Act 1999* (Cth) ss 10, 11 (Austl.); *Air Navigation Act 1937* (Qld) ss 16, 17 (Austl.); *Civil Liability Act 2002* (NSW) s 73 (Austl.); *Civil Liability Act 1936* (SA) s 61 (Austl.); *Damage by Aircraft Act 1963* (Tas) s 4 (Austl.); *Wrongs Act 1958* (Vic) s 31 (Austl.); *Damage by Aircraft Act 1964* (WA) s 5 (Austl.).

[193] *Criminal Code Act 1995* (Cth) s 6.1 (Austl.).

This means that the other areas of law which might be applied—such as negligence; nuisance; and trespass to land, persons, or goods—are less likely to be attractive to a plaintiff because strict liability is easier to prove than these fault-based torts.[194] However, this does not mean that a plaintiff may not choose to sue both under Damage by Aircraft legislation and the other causes of action available. Also, it will remain possible to sue for consumer law claims, interference to privacy (in some situations), trespass to land, and nuisance.[195]

A. Damage by Aircraft

In Australia, the *Damage by Aircraft Act 1999* (DAA) and its state counterparts establish strict liability for surface damage caused by an aircraft in flight.[196] Based on an examination of each element, a drone would fall within the scope of this legislation.

1. *Scope of Legislation*

a. Aircraft

The DAA applies to Australian and foreign "aircraft"[197] and to aircraft owned by foreign, trading, or financial corporations (within the meaning of paragraph 51 (xx) of the Australian Constitution).[198] The Act is subject to the constitutional limitations of Commonwealth legislative powers.[199] Consequently, intrastate aircraft operations by non-corporations are not within the scope of the DAA and must be subject to state enact-

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194 *See* Hyewon Hannah Choi, Comment, *Delivery Drones: Inapt for Application of Current Negligence Theory*, 86 J. Air L. & Com. 435, 456 (2021).

195 *See id.* at 438.

196 *Damage by Aircraft Act 1999* (Cth) s 11 (Austl.) (applying to ACT and NT as well); *Air Navigation Act 1973* (Qld) s 17(2) (Austl.); *Civil Liability Act 2002* (NSW) s 73(1) (Austl.); *Civil Liability Act 1936* (SA) s 61(3) (Austl.); *Damage by Aircraft Act 1963* (Tas) s 4(1) (Austl.); *Wrongs Act 1958* (Vic) s 31(1) (Austl.); *Damage by Aircraft Act 1964* (WA) s 5(1) (Austl.).

197 Section 4 of the Act provides that "aircraft has the same meaning as in the *Civil Aviation Act 1988*, but does not include model aircraft." *Damage by Aircraft Act 1999* (Cth) s 4 (Austl.). Defence Force Aircraft are also excluded. *Id.* s 9(2).

198 *Id.* s 9(4)(b). The Act also applies to air navigation in or to or from Australian territories, and to aircraft engaged in international air navigation, or in trade or commerce internationally, or amongst the Australian states, or to aircraft landing at or taking off from places held by the Commonwealth. *Id.* s 9(4)(c); Stewart, *supra* note 86, at 8.

199 *Australian Constitution* s 51 (including corporations (xx), external affairs (xxix)), overseas and interstate trade and commerce (i), and matters incidental to any of the Commonwealth's powers (xxxix)).

ments.[200] An aircraft is defined as "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."[201] An RPA would thus be classified as an aircraft and be subject to the DAA. However, recreational model aircraft are excluded.[202]

b. In Flight

Drones are classified as "power-driven aircraft [which are] heavier than air" and accordingly will be "in-flight from the moment when power is applied for the purpose of take-off until the moment when [the] landing run ends."[203]

c. Surface Damage

Surface damage occurrences are those where "a person or property on, in, or under land or water suffers personal injury, loss of life, material loss, damage, or destruction" caused by any of the following:

> (a) an impact with an aircraft . . . in flight[204] . . . ; or
> (b) an impact with part of an aircraft that was damaged or destroyed while in flight;[205] or
> (c) an impact with a person, animal or thing that dropped or fell from an aircraft in flight;[206] or
> (d) something that is a result of an impact of a kind mentioned in [the preceding list].[207]

While the most basic kind of contemplated incident of a drone motor failure leading to a crash and surface damage would clearly be covered by the DAA, scenarios where the injury

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[200] *Airlines of N.S.W. Pty Ltd v New South Wales [No. 2]* (1965) 113 CLR 54 (Austl.); Ronald IC Bartsch, Commentary, *Statutory Provisions Affecting Surface Damage Liability*, *in* THE LAWS OF AUSTRALIA para 34.2.7010 (2020) [hereinafter Bartsch Commentary]. For example, it would not apply to RPAs operated by natural persons, unincorporated associations, or partnerships engaged in commercial activities within state borders.

[201] *Civil Aviation Act 1988* (Cth) s 3 (Austl.). A similar definition appears in other statutes, such as the *Air Navigation Act 1920* (Cth) s 3(1) (Austl.).

[202] *Damage by Aircraft Act 1999* (Cth) s 4 (Austl.). However, in some states and territories, it may be that all drones are subject to the legislation, including recreational units, depending on the definition of "aircraft" adopted. *See* Stewart, *supra* note 86, at 16–17.

[203] *Damage by Aircraft Act 1999* (Cth) s 5(2) (Austl.) (alteration in original).

[204] *Id.* s 10(1)(a) (alteration in original).

[205] *Id.* s 10(1)(b).

[206] *Id.* s 10(1)(c).

[207] *Id.* s 10(1)(d) (alteration in original).

or damage was not caused by the impact of the crash itself raise more complex legal issues. This involves an examination of the legal scope of damage. As Stewart points out, difficulty may arise in the definition of the scope of damage because of the differences between the Commonwealth and state enactments of the DAA.[208]

In NSW, Tasmania, Victoria, and Western Australia, the strict liability provision does not depend on an impact and does not refer to something that is a result of an impact with an aircraft.[209] Thus, all that is required is direct causation of damage by an aircraft in flight. The Acts also expressly extend to "take off" and "landing," which seemingly enlarges the temporal ambit of these provisions.[210]

However, in the Queensland and South Australia provisions, similar to the Commonwealth provisions, because damage must follow some impact, liability applies to a narrower range of incidents.[211] South Australia also excludes damages during agricultural purposes, firefighting, pollutant dispersal, and similar operations, leaving any injury caused by the specified activities to be subject to common law principles.[212]

2. *State Legislation–Scope of Damage*

The distinction between the scope of damage contemplated by the legislation is demonstrated in case law. The NSW law was applied in *Southgate v Commonwealth* when a plaintiff riding a horse along the beach was injured by a helicopter that hovered over her.[213] The crew sought to get a better view to observe her, which startled the horse and caused the plaintiff to be thrown off and dragged along the ground as her right foot was caught in the stirrup.[214] The plaintiff sued for damages, alleging negligence and entitlement to damages under the *Damage by Aircraft Act 1952*,[215] and was awarded $500,000.[216]

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[208] Stewart, *supra* note 86, at 10.

[209] *Civil Liability Act 2002* (NSW) s 73(1) (Austl.); *Damage by Aircraft Act 1963* (Tas) s 4(1) (Austl.); *Wrongs Act 1958* (Vic) s 31(1) (Austl.); *Damage by Aircraft Act 1964* (WA) s 5(1) (Austl.).

[210] Bartsch Commentary, *supra* note 200.

[211] *Air Navigation Act 1937* (Qld) s 16 (Austl.); *Civil Liability Act 1936* (SA) s 61(5) (Austl.).

[212] *Civil Liability Act 1936* (SA) s 61(5) (Austl.).

[213] *Southgate v Commonwealth* (1987) 13 NSWLR 188, 189 (Austl.).

[214] *Id.*

[215] Note that this Act has since been subsumed into the *Civil Liability Act 2002* (NSW) s 73 (Austl.).

The defendant argued that due to the plaintiff's share in the responsibility of damage, the court was required to treat the plaintiff's claim as contributory negligence in order to properly assess the qualities of the defendant's act.[217] Justice Brownie rejected the claim and held that the test for liability under the DAA is "direct causation" of damage on the surface by an aircraft in flight rather than a direct impact.[218] Justice Brownie further stated:

"[T]he rationale behind the *Damage by Aircraft Act* is based wholly on fairness, considering the inequality between the parties where one is wholly at the risk of the other, and has not even voluntarily exposed himself to the risks[.]"[219]

In relation to drones, an analogous argument can be made that a similar nexus of inequality exists between the drone operator and a civilian on the ground who has not voluntarily exposed themselves to the risks of a drone flying overhead. Regarding the scope of damage, the reasoning in *Southgate v Commonwealth* is likely to apply under the NSW DAA, widening the ambit of liability to include indirect damage.

3. *Commonwealth Legislation–Scope of Damage*

In comparison, the first Commonwealth test of the Commonwealth DAA's scope was in *ACQ Pty Ltd v Cook; Aircair Moree Pty Ltd v Cook (Cook),* where the NSW District Court,[220] NSW Court of Appeal,[221] and the High Court[222] considered the nature of the causal link required between the impact of an aircraft and the resulting damage to a person on the ground. In *Cook*, the defendant's aircraft collided with a power line, dealing damage to the pole and causing it to hang 1.5 meters off the ground.[223] The plaintiff was sent to repair the power line but was electrocuted from an electrical arc after he accidentally fell onto wet ground.[224]

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216 *Southgate*, 13 NSWLR at 191 (Austl.).

217 *Id.* at 189.

218 *Id.*

219 *Id.* at 191 (alteration in original).

220 *Cook v Aircare Moree Pty Ltd* [2007] NSWDC 164 (Austl.).

221 *ACQ v Cook; Aircair Moree v Cook; Cook v Country Energy; Country Energy v Cook* [2008] NSWCA 161 (Austl.).

222 *ACQ Pty Ltd v Cook; Aircair Moree Pty Ltd v Cook* [2009] HCA 28 (Austl.) (joint decision delivered by the bench comprising French CJ, Gummow, Heydon, Crennan, and Bell JJ).

223 *Id.* at para 1.

224 *Id.*

The aviation defendants argued the plaintiff's injuries fell outside the scope of the Commonwealth DAA because "'something that is a result of an impact' . . . should be construed as being a thing (for example, a fire or a collapse of a building) which 'has an immediate (or reasonably immediate) temporal, geographical and relational connection with an impact.'"[225] The High Court rejected this argument and instead took a broader reading stating, "[t]he injury was caused by the dangerous position of the conductor, and its dangerous position was the result of an impact between the aircraft and it."[226]

Thus, while the NSW and Commonwealth legislation differ semantically on the scope of damage, it seems that the interpretation by courts on construction reaches analogous conclusions. As Stewart points out, the Commonwealth causation requirement, as interpreted by the High Court in *Cook*, would encompass most conceivable instances of damage by RPA on the ground and would include both direct damage and potentially indirect damage from the impact.[227]

The High Court also emphasized that "[m]ost cases on s 10(1) are likely to be intensely fact-specific."[228] In the course of illustrating the scope of the provision, the defendants posited a scenario where a plane explodes on landing and sets a nearby structure on fire, causing death or injury to a plaintiff and property damage to their house.[229] The defendants argued that while a firefighter as an urgent rescuer would be protected by the scope of the legislation, a linesman who came to address the danger precisely "because of their skills, experience and position, occupation, in order to repair or rectify that dangerous position where there is no peril to another person" would not be within the legislation's scope.[230] The High Court rejected this and found that there clearly was the presence of a peril to another person.[231] The damaged conductor pole in this case posed a danger to agricultural workers and others in the area.[232] In a similar vein, a drone crash can be the catalyst for major losses,

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225 *Id.* at para 10.

226 *Id.* at para 18.

227 Stewart, *supra* note 86, at 12.

228 *ACQ Pty Ltd v Cook; Aircair Moree Pty Ltd v Cook* [2009] HCA 28 para 14 (Austl.) (alteration in original).

229 *Id.* at para 15.

230 *Id.*

231 *Id.* at para 16.

232 *Id.*

such as the sparking of fires or explosions, and in such a circumstance a court may rely on similar logic to hold a drone operator liable for generating peril to persons beyond the impact.[233]

Thus, where a drone bearing failure causes a crash onto a property, inciting a perilous situation, any casualties that result from the situation can give rise to a strict liability claim under Damage by Aircraft legislation. Additionally, under the Commonwealth DAA, if the plaintiff was contributorily negligent, liability will still be imputed but subject to limitations on damages.[234] Even if the chances of the drone bearing failure were minuscule, or the cause was due to a third party, fault will still lie with the RPA operator. The only way to avoid liability under Damage by Aircraft legislation is to prevent the injury or damage from occurring in the first place. This is a highly onerous standard of care that highlights the importance of a system like condition monitoring, which may be the only way to prevent such damage.

This raises questions about whether the current statutory framework is appropriate. Applying the Damage by Aircraft legislation without specific recognition and amendment for drones may generate unfair outcomes for operators. The most obvious scenario is when the crash is caused by an inherent defect, at no fault of an otherwise compliant operator. The operator can still be held accountable, and in cases where the manufacturer's solvency is questioned, the operator is a natural target for the recovery of damages. The manufacturer, the operator, the operator's employer, and the owner are all possible defendants. This provides a strong legal impetus for the operator to use drone motor bearing condition monitoring technology to preemptively prevent the harm from materializing at all.

4. *Psychiatric Injury*

The Commonwealth Act only covers consequential psychiatric injury. This means that the person is only compensated for psychiatric injury if the person suffering from the psychiatric harm first suffers physical loss or damage.[235] South Australia mirrors the Commonwealth Act and thus would also require a plaintiff to bring a cause of action in the common law for a purely

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[233] Thompson et al., *supra* note 28, at 4.

[234] *Damage by Aircraft Act 1999* (Cth) s 11A (Austl.). Note, however, strict liability will not apply in NSW, Victoria, WA, and Tasmania. See *infra* Section IV.B.

[235] *Id.* at s 10(1A).

mental injury.[236] However, in other states and territories, purely mental harm may be claimed under strict liability Damage by Aircraft legislation.[237]

5. *Pure Economic Loss*

Recovery for solely economic loss is recovery for economic losses not causally consequential upon damage or loss of tangible property. This would refer, for example, to loss of business because of a failure of delivery. It has been suggested that the terminology in section 10(1)(a), stating that "an impact with an aircraft that is in flight, or that was in flight immediately before the impact happened,"[238] would mean that pure economic loss is probably outside the scope of the Commonwealth provisions.[239] This would also preclude South Australia, which applies the Commonwealth provisions.[240] While the scope of damage is broader in the other states and territories, direct causation is still required, which suggests that purely economic loss will be excluded.

6. *Trespass or Nuisance*

In certain states, the act of only flying an aircraft (mere flight) over a property does not constitute trespass or nuisance, so long as the aircraft is flown in compliance with the *Air Navigation Regulation 2016* and at a reasonable height with regard to the wind, weather, and other circumstances.[241]

This provision would not apply where a bearing failure leads the drone or drone part to fall to the ground because this is

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[236] Stewart, *supra* note 86, at 14.

[237] *See Civil Liability Act 2002* (NSW) s 73(1) (Austl.); *Damage by Aircraft Act 1963* (Tas) s 4(1) (Austl.); *Wrongs Act 1958* (Vic) s 31(1) (Austl.); *Damage by Aircraft Act 1964* (WA) s 5(1) (Austl.). For limitations on recovery for mental injury, see *Civil Liability Act 2002* (NSW) pt 3 (Austl.); *Civil Liability Act 2002* (Tas) pt 8 (Austl.); *Civil Liability Act 1936* (SA) s 33 (Austl.); *Wrongs Act 1958* (Vic) pt XI (Austl.); *Civil Liability Act 2002* (WA) s 5S (Austl.); *Civil Law (Wrongs) Act 2002* (ACT) pt 3.2 (Austl.).

[238] *Damage by Aircraft Act 1999* (Cth) s 10(1)(a) (Austl.).

[239] Bartsch Commentary, *supra* note 200.

[240] *Civil Liability Act 1936* (SA) s 61(1)–(3) (Austl.).

[241] *Air Navigation Regulation 2016* (Cth) (Austl.) (for example, licensing and timetable approval). *See, e.g.*, *Civil Liability Act 2002* (NSW) s 72 (Austl.); *Civil Liability Act 1936* (SA) s 62 (Austl.); *Damage by Aircraft Act 1963* (Tas) s 3 (Austl.); *Wrongs Act 1958* (Vic) s 30 (Austl.); *Damage by Aircraft Act 1964* (WA) s 4 (Austl.). There are no equivalent provisions in the Australian Capital Territory, the Northern Territory, or Queensland. Such provisions are common and virtually identical throughout Australia and other Commonwealth countries.

outside the scope of mere flight.[242] Thus, "where damage was done to any persons on the ground, the owner of the offending aircraft would be liable without forcing the injured person to prove negligence" or nuisance.[243]

Where there is only noise, a creative argument can be made that the impact of noise and vibrations may cause personal injury or property damage by way of "something that is a result" of such an impact, even if not directly.[244] For example, one such impact may exist where the delivery drone in the course of its descent generates strong noise or vibrations due to a dysfunctional motor, and startles a person or even a nervous pet into causing damage. However, complying with relevant regulations and noise certifications would nullify any cause of action.[245] Because noncompliance with these regulations would be relatively rare by a prudent operator, very few instances of aircraft noise or vibration may be actionable even when physical damage occurs.[246] A bearing monitoring device would make such an occurrence even rarer because any motor issue can be resolved as it happens. In these circumstances, aggrieved plaintiffs will need to turn to the common law torts of negligence, trespass, or nuisance to litigate their claims.[247]

7. *Damaged Goods*

Strict liability does not extend to people or goods onboard the aircraft, but other legislation deals with this.[248] Thus, a bear-

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[242] *See* Glen v. Korean Airlines Co. Ltd. [2003] EWHC 643 (QB) [6], [8] (Eng.).

[243] *Id.* at [29].

[244] Noise and vibrations may also give rise to a claim in nuisance. *See infra* Part VIII.

[245] Bartsch, *supra* note 200.

[246] *Id.* at para 34.2.7050.

[247] *See infra* Part V.

[248] *See Civil Aviation (Carriers' Liability) Act 1959* (Cth) ss 28–29 (Austl.). The Commonwealth Act applies to the Australian Capital Territory and the Northern Territory. *Id.* s 7(1). Complementary legislation in the various States applies the following Commonwealth provisions: *Civil Aviation (Carriers' Liability) Act 1967* (NSW) s 5 (Austl.); *Civil Aviation (Carriers' Liability) Act 1964* (Qld) s 5 (Austl.); *Civil Aviation (Carriers' Liability) Act 1962* (SA) s 6 (Austl.); *Civil Aviation (Carriers' Liability) Act 1963* (Tas) s 5 (Austl.); *Civil Aviation (Carriers' Liability) Act 1961* (Vic) s 5 (Austl.); *Civil Aviation (Carriers' Liability) Act 1961* (WA) s 6 (Austl.). *See also Leith v Medhurst* [1991] 2 VR 362, 365–66 (Austl.) (citing Steel-Maitland v. Brit. Airways Bd. (1981) SLT 110, 110–112 (Scot.)); *Compensation for Damages & Loss*, AUSTRALIAN COMPETITION & CONSUMER COMM'N, https://www.accc.gov.au/consumers/consumer-rights-guarantees/compensation-for-damages-loss#what-compensation-is-covered- [https://perma.cc/W263-HTFL].

ing failure that causes damage to cargo would require a claim under the Australian Consumer Law to recover the cost of goods lost in transit.

B. Damages

Damages can be recovered against all owners, pilots, and operators of the aircraft involved immediately before the impact occurred.[249] They are jointly and severally liable,[250] except where there is a lease or agreement.[251] A person using an aircraft is taken as its "operator" unless the person authorizing such use retains control over navigating the aircraft.[252] State and territorial occupational health and safety laws also apply to drone operators.[253]

While *Cook* held the defense of contributory negligence was not available due to a lack of clarity in the law, an amendment now allows contributory negligence to reduce amounts of compensation.[254] In NSW, Western Australia, Tasmania, and Victoria, state provisions exclude claims from Damage by Aircraft legislation where the plaintiff was negligent.[255] Claimants in these states would have to bring a claim in common law and face the possibility of a contributory negligence defense.[256]

The court in *Cook* held that limitations on damages also apply.[257] Part 2 of the *Civil Liability Act 2002* (NSW) applies to all awards of personal injury damages whether "brought in tort, in

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249 In the event of a collision between two or more aircraft in flight, liability applies to each of the aircraft. *Damage by Aircraft Act 1999* (Cth) s 10(4) (Austl.).

250 *Id.* s 10(2).

251 *Id.* s 10(2A)(c)(i).

252 *Id.* s 6.

253 *See, e.g.*, *Work Health Auth v Outback Ballooning Pty Ltd* (2019) HCA 2, para 60 (Austl.).

254 *Aviation Legislation Amendment (Liability and Insurance) Act 2012* (Cth) s 6 (Austl.), which inserted s 11A titled "Contributory negligence" into *Damage by Aircraft Act 1999* (Cth) (Austl.). *See also ACQ v Cook; Aircair Moree v Cook; Cook v Country Energy; Country Energy v Cook* [2008] 72 NSWLR 161, para 212 (Campbell, JA.).

255 *Civil Liability Act 2002* (NSW) s 73(1) (Austl.); *Damage by Aircraft Act 1963* (Tas) s 4(1) (Austl.); *Damage by Aircraft Act 1964* (WA) s 5(1) (Austl.); *Wrongs Act 1958* (Vic) s 31(1) (Austl.); Victorian Competition & Efficiency Comm'n, Adjusting the Balance: Inquiry into Aspects of the *Wrongs Act 1958*, at 114 (2014), https://www.dtf.vic.gov.au/sites/default/files/2018-02/adjusting-the-balance-inquiry-into-aspects-of-the-wrongs-act-1958.pdf [https://perma.cc/A76T-QKAZ].

256 Stewart, *supra* note 86, at 13–14.

257 *Cook*, 72 NSWLR at 350 para 109.

contract, under statute or otherwise;"[258] this also applies to other states except South Australia.[259]

Currently, while there is some uncertainty in a DAA claim depending on the state the claim is based in, the Australian government has emphasized that, in the future, it aims to coordinate across the Commonwealth, State, and Territory governments to achieve a nationally consistent approach.[260]

V. NEGLIGENCE

While a drone equipped with a bearing monitoring device that crashes might well create strict liability, the device would be useful in fault-based torts such as negligence or nuisance. It can be used as evidence of reduced fault, showing that the operator or manufacturer had taken reasonable steps to prevent a known risk from materializing.

A plaintiff who has suffered personal injury or damage to property will likely turn to the tort of negligence. Negligence is a broad right of redress for harm caused by a failure to take reasonable care when a person owes a duty of care to someone whom it is reasonably foreseeable may be harmed by the first person's act or omission.[261] To succeed, plaintiffs need to show that the defendants owed them a duty of care, which they breached, and that the breach caused harm to the plaintiffs.[262] Each element will be addressed in turn.

A. Duty of Care

First, a plaintiff must establish that a duty of care was owed by the defendant to a class of persons of which the plaintiff belongs.[263] In personal injury and death cases, it is relatively easy to establish a duty exists if it was reasonably foreseeable that a person in the plaintiff's position might be harmed by the defendant's actions or failure to act.

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258 *Civil Liability Act 2002* (NSW) s 11A (Austl.).

259 *Civil Liability Act 2003* (Qld) s 50 (Austl.); *Wrongs Act 1958* (Vic) ss 28C, 28LC (Austl.); *Civil Liability Act 2002* (WA) s 6 (Austl.); *Civil Law (Wrongs) Act 2002* (ACT) s 93 (Austl.); *Personal Injuries (Liabilities and Damages) Act 2003* (NT) pt. 4 (Austl.); *Civil Liability Act 1936* (SA) s 51 (Austl.); *Civil Liability Act 2002* (Tas) s 24 (Austl.).

260 Policy Issues, *supra* note 18, at 54.

261 Perritt, Jr., *supra* note 17, at 24.

262 *Id.* at 23.

263 *Chapman v Hearse* (1961) 106 CLR 112, 121 para 6 (Austl.).

In the event of an RPA crash, possible defendants might include the operator, the owner, the manufacturer, the distributor, the person responsible for maintenance, and possibly the designer. Where that crash is caused by a bearing failure, this Article focuses on the two most likely parties an aggrieved plaintiff may litigate against: the RPA operator and the RPA manufacturer.

1. Operator

In the *Cook* cases, the NSW Court of Appeal recognized that the pilot "may have owed a duty to people on the ground who might be injured if the plane or anything dropped from it struck them or caused them to injure themselves while taking evasive action."[264] They also recognized that it is reasonably foreseeable that an aircraft pilot flying a plane in a fashion that could pull down a power line would bring repairpersons to the scene who could then injure themselves.[265] However, it was not reasonably foreseeable that the "power authority would send a person who was not properly trained, experienced, and capable of protecting [themselves]."[266] No duty was imposed in the latter circumstance.

Where a falling delivery drone causes physical injury from the negligent act of an operator, in the absence of specific authority or precedent, general principles of negligence apply.[267] Applying these involves determining whether the risk of injury was reasonably foreseeable and whether the "salient features"[268] of the case lend themselves to a duty being established.[269] In this case, a duty likely exists because there is clearly foreseeable risk of harm to people or property on the road if the drone malfunctions in the course of performing its delivery operations in some way. Some salient features would also favor a duty of care given the vulnerability of potential plaintiffs on the ground,[270] the degree of control by a defendant operator,[271] and the policy con-

264 *ACQ v Cook; Aircair Moree v Cook; Cook v Country Energy; Country Energy v Cook* [2008] NSWCA 161, 337 para 99 (Campbell, JA.).

265 *Id.* at 338 para 101.

266 *Id.* (alteration in original).

267 *See, e.g.*, Donoghue v. Stevenson [1932] AC 562 (HL) 564 (appeal taken from Scot.) (UK).

268 *Graham Barclay Oysters Pty Ltd v Ryan* [2002] HCA 54 para 149 (Austl.).

269 *Chapman v Hearse* (1961) 106 CLR 112, 121 para 6.

270 *See Perre v Apand Pty Ltd* [1999] HCA 36 para 15 (Austl.).

271 *Graham Barclay Oyster Pty Ltd V Ryan* [2002] HCA at para 20.

siderations to hold negligent operators and manufacturers accountable for their actions. The counterargument is that operators have a restricted range at which a drone is controllable, and beyond that range, it is not controlled by anyone.[272] For autonomous drones, the question of control may be an entirely different matter. In that case, it will probably be a matter of the manufacturer's negligence rather than the negligence of the operator.[273]

2. *Manufacturer*

In 1932, the court in *Donoghue v Stevenson*[274] found a duty of care existed between the manufacturer and consumer. This is also known as product liability. A duty of care is not restricted to only the ultimate consumer or user but extends to "innocent bystanders"—i.e., "everyone within the foreseeable range of the product's harmful effects."[275] For example, like how a manufacturer of a defective car owes a duty to road users,[276] car repairers,[277] and any person endangered within "the vicinity of its probable use;"[278] a drone manufacturer would similarly owe a duty of care to civilians on the ground to manufacture an airworthy drone. Otherwise, it is reasonably foreseeable that a defective RPA may cause bodily harm, property damage, or economic loss to users or people struck by it during use.

Product liability is also not restricted only to the original manufacturer of goods. Other parties in a supply chain, whether it be suppliers, importers, distributors, or maintenance organizations, can owe a duty of care to all foreseeable persons affected by the aircraft.[279] In the case of aviation motor bearings, liability most often arises from negligent maintenance.[280] For instance,

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[272] Perritt, Jr., *supra* note 27, at 69.

[273] *See infra* Section V.C.

[274] Donoghue v. Stevenson [1932] AC 562 (HL) 564 (appeal taken from Scot.) (UK).

[275] FLEMING'S THE LAW OF TORTS 557 (Carolyn Sappideen & Prue Vines eds., 10th ed. 2011).

[276] Stennett v. Hancock [1939] 2 All ER 578 (KB) (Eng.); Marschler v. G. Masser's Garage, [1956] 2 D.L.R. (d) 484, para 12 (Can. Ont. H.C.).

[277] Hobbs Mfg. v. Shields, [1962] S.C.R. 716, 718 (Can.). *But see Daley v Gypsy Caravan Co Pty Ltd* [1966] 2 NSWR 22, 29 (Austl.) (deciding that the car repairer's injury from the manufacturer's mistake was not foreseeable).

[278] FLEMING'S THE LAW OF TORTS, *supra* note 275, at 557.

[279] *See* BARTSCH, *supra* note 91, at 490.

[280] *See id.*

in *Cifuentes v Fugro Spatial Solutions*,[281] an aeronautical engineer appointed by CASA incorrectly advised that a sleeve bearing could be replaced with aluminum bronze alloy, which led the engine to fail and the plane to crash.[282] The court found a duty was owed to the passengers of the aircraft because it was reasonably foreseeable that using an unsuitable alloy and unsatisfactory finish would increase the risk of bearing failure, endangering the aircraft passengers.[283]

However, while a manufacturer can owe duties to a wider class of persons, not everyone who is injured is necessarily within the class of "neighbor."[284] For example, in *Daley v Gypsy Caravan Co*,[285] no duty of care was found between the manufacturer and a qualified electrician who was electrocuted by a copper pipe in a caravan after the repairman exercised an error of judgment. While it could be expected for an electrician to interact with the copper pipe, the manufacturer could not have reasonably anticipated that the plaintiff would choose to incur the "risk of mischance" during his repair attempt.[286] No duty was found in those circumstances. By a similar stream of logic, a repairperson sent to repair a crashed drone who does not wear gloves and is consequently electrocuted would likely not be captured within the manufacturer's duty of care.[287]

B. Breach

Having established that a duty of care exists and is owed to citizens on the ground, the next step is considering whether that duty is breached when a drone falls to the ground and causes damage. It is this element of breach that provides the strongest legal rationale for using a bearing monitoring device. The proper use of a device can provide a compelling argument that the operator or manufacturer was endeavoring to meet the reasonable standard of care that was required of them.

To establish that a breach has occurred, it must be established that the defendant fails to respond like a reasonable person

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281 *Cifuentes v Fugro Spatial Sols Pty Ltd* [2009] WASC 316 (Austl.).

282 *Id.* at paras. 1, 276-78.

283 *Id.* at paras. 278-279.

284 *Daley v Gypsy Caravan Co Pty Ltd* [1966] 2 NSWR 22, 26 (Austl.); *ACQ Pty Ltd v Cook; Cook v Country Energy; Country Energy v Cook* [2008] 72 NSWLR 318, 335, para. 87. *See Grant v Australian Knitting Mills Ltd* [1936] AC 85, 104-05 (Austl.).

285 *Daley*, 2 NSWR at 22.

286 *Id.* at 28–29.

287 Contributory negligence would also be a factor to consider.

would to a foreseeable risk or injury.[288] Determining the proper response requires weighing the likelihood of the harm, gravity of harm, ease of avoiding harm, and other issues.[289] Failure to act like the reasonable person will mean that breach is proven.[290] Matters that are likely to be regarded as breaches would include failure to properly maintain bearings and failure to keep a proper lookout when piloting the aircraft.

In the case of RPAs, the risk of harm is also likely to be not insignificant. This is a question of the probability of the risk eventuating, not the magnitude of the resulting harm.[291] Research has emphasized that generally drones are not very reliable systems.[292] One study found RPA mishaps happen at a rate 100 times higher than crewed aircraft, with fifty percent being attributed to aircraft failure.[293]

It is submitted that an operator or manufacturer using a drone bearing monitoring device has substantially more favorable chances of discharging their duty of care than an entity that is not using this device when a bearing-related incident occurs. First, while the consequence of an airborne drone falling on someone or something due to a bearing fault could indeed be reasonably foreseeable, with the installation of a drone bearing monitoring device, the probability of it happening from a one-off flight could become so improbable that it would not be reasonable to do anything about it.[294]

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288 *Civil Liability Act 2002* (NSW) s 5B(1)(a) (Austl.); *Civil Liability Act 2003* (Qld) s 9(1)(a) (Austl.); *Civil Liability Act 1936* (SA) s 32(1)(a) (Austl.); *Civil Liability Act 2002* (Tas) s 11(1)(a) (Austl.); *Wrongs Act 1958* (Vic) s 48(1)(a) (Austl.); *Civil Liability Act 2002* (WA) s 5B(1)(a) (Austl.); *Civil Law (Wrongs) Act 2002* (ACT) s 43(1)(a) (Austl.).

289 *Civil Liability Act 2002* (NSW) s 5B(2) (Austl.).

290 *Id.* s 5B(1)(c). Traditionally under common law, a foreseeable injury is not far-fetched or fanciful. *Wyong Shire Council v Shirt* (1980) 146 CLR 40, paras. 13–15 (Austl.).

291 *Benic v New South Wales* [2010] NSWSC 1039, para 101(c) (Austl.).

292 Yap, *supra* note 20, at 3; *see also* Wild et al., *supra* note 35, at 1–2.

293 Alberto Susini, *A Technocritical Review of Drones Crash Risk Probabilistic Consequences and Its Societal Acceptance*, *in* 7 LECTURE NOTES IN INFORMATION SCIENCES: RISK INFORMATION MANAGEMENT, RISK MODELS, AND APPLICATIONS 27, 29 (2015), https://www.researchgate.net/profile/Alberto-Susini-2/publication/291697791_A_Technocritical_Review_of_Drones_Crash_Risk_Probabilistic_Consequences_and_its_Societal_Acceptance/links/56a5365a08ae232fb207a641/A-Technocritical-Review-of-Drones-Crash-Risk-Probabilistic-Consequences-and-its-Societal-Acceptance.pdf [https://perma.cc/UU52-KAYN].

294 Bolton v. Stone [1951] AC 850 (HL) (Eng.).

The counterargument to this would be that everyday fleets of delivery drones, operating beyond the line of sight or over densely populated neighborhoods and cities, would amplify the probability of such an incident beyond merely a remote risk.[295] Yet again, the addition of a bearing condition monitoring device would reduce the likelihood of this scenario. Assuming the monitoring device does not fail, it is far less probable for a drone aircraft to experience catastrophic failure and fall. Using such a device could provide persuasive evidence that the operator or manufacturer sought to meet the standard of reasonable care during a bearing-related incident.

Second, the drone bearing condition monitoring system can reduce the gravity of harm from a falling freight drone. For freight drones, the seriousness of harm is high, not just from their larger size but also from their cargo.[296] For certain drones, a condition monitoring device may reduce an excessive allocation of weight to redundancy systems, lowering the weight of the RPA and the potential gravity of harm it can cause.[297] For lighter drones, CASA has itself acknowledged that micro-RPAs have low kinetic energy and pose little risk to people and property.[298] Some scholars also share this view, finding it difficult to imagine how a crash of smaller drones, such as survey RPAs, could cause serious injury.[299]

Nonetheless, other academics have rebutted that argument on the basis that the kinetic force generated from even a small drone falling from a height of up to 120 metres (400 feet) can cause significant damage.[300] Further, the sharp edges on the propellers can cause "more substantial physical and mental trauma than the drone's mass and velocity alone suggest."[301] Citizens are also more vulnerable to injuries from above them as it is hard to see the falling object, and there will be less time to take evasive action.[302] These innate characteristics of drones sug-

295 Perritt, Jr., *supra* note 27, at 65–66.

296 HODGKINSON & JOHNSTON, *supra* note 12, at 25.

297 Perritt, Jr., *supra* note 27, at 46.

298 AUSTL. CIV. AVIATION SAFETY AUTH., NOTICE OF PROPOSED RULE MAKING (1309OS): REMOTELY PILOTED AIRCRAFT SYSTEMS 3.1.2 (2014); Terry Farquharson, CASA Deputy Director of Aviation Safety, Speech at the Sir Richard Williams Foundation Seminar, Canberra: UAVs (Drones) in Civil Airspace and Challenges for CASA (July 3, 2013).

299 Perritt, Jr., *supra* note 27, at 64–65.

300 Stewart, *supra* note 86, at 7.

301 Clarke & Moses, *supra* note 23, at 264; Perritt, Jr., *supra* note 27, at 69.

302 Clarke & Moses, *supra* note 23, at 264.

gest a certain seriousness of harm is unavoidable. In this case, preemptive detection with bearing monitoring to prevent harm remains the best legal avenue for avoiding liability.

Third, a defendant can argue that there would be an undue burden in taking any further steps to avert the foreseeable harm of a drone falling. This element is often compared with the magnitude of the harm, so cases often hold defendants liable where the risk of harm is high but actions to avoid them are not overly burdensome.[303] Installing a drone bearing condition monitoring system shows a defendant has actively taken steps to prevent harm from a bearing fault. Courts may then consider that any further precautions may make drones prohibitively expensive and defeat their commercial purpose.[304]

An argument could also be made that no technology is absolutely reliable and extremely rare mechanical failures should be treated in the same way as "Acts of God"—being environmental incidents such as severe turbulence and lightning—which are foreseeable but unpreventable.[305] However, it is unlikely that this argument would be accepted without weighing up all the other factors mentioned.

Finally, there is social utility in delivery drones being allowed to operate without overbearing restrictions. Drone-based delivery can generate substantial social utility by reducing economic costs, lowering emissions, and even potentially saving lives through just-in-time healthcare deliveries.[306] Wing has proven it can successfully and effectively transport the likes of meals, groceries, medicines, and even heavier items such as spare car parts.[307] This utility was particularly pronounced during the COVID-19 pandemic, with Wing drones seeing a 500% increase in use from February to April in 2020.[308] Condition monitoring of drones can ensure the efficient operation of these fleets while

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303 *Haileybury Coll. v Emanuelli* [1983] 1 Vic 323 (Austl.); *see also Romeo v Conservation Comm'n of The Northern Territory* (1998) 192 CLR 431, paras. 50, 69 (Austl.); *Roads & Traffic Auth of NSW v Dederer* (2007) 234 CLR 330, para 3 (Austl.).

304 INST. FOR LEGAL REFORM, *supra* note 49, at 2–3.

305 Clarke & Moses, *supra* note 23, at 264.

306 Oosedo et al., *supra* note 3, at 348.

307 *About Delivery: Learn About How Wing Delivery Works*, WING, https://wing.com/about-delivery/ [https://perma.cc/SC7Q-2RCD].

308 Sharon Masige, *Alphabet's Drone Delivery Service Wing Has Made 'Thousands' of Deliveries in Australia During the Pandemic*, BUS. INSIDER AUSTL. (May 25, 2020, 1:27 PM), https://www.businessinsider.com.au/alphabets-drone-delivery-service-wing-has-made-thousands-of-deliveries-in-australia-during-the-pandemic-2020-5 [https://perma.cc/23SV-9LQZ].

also minimizing costs and liability through a more precise system of maintenance.

1. Operator

Despite the strength of these arguments, it is important to recall that RPAs are subject to extensive safety regulations. While a breach of any statutory or regulatory provision will not in of itself necessarily signal liability in a common law determination, in some circumstances it could.[309] For example, an RPA operator who flies at night to complete a late delivery when their CASA permit is only valid for daytime flights could be regarded as failing a reasonable person's standard of care which is to comply with regulations.

Consequently, an operator cannot depend exclusively on using a drone bearing monitoring device or other means of technology to meet their standard of care. Even if the device is marketed to be absolutely accurate and the operator wholly relies on such a marketing claim, yet the device fails, the operator may still be liable for a breach of duty if the operator had failed in their obligations, such as performing the maintenance at the level expected of a reasonable operator as required by the regulations.[310] For example, one requirement found in the MOS is the keeping of a technical log, which records essential information relating to the continuing airworthiness of the RPA.[311] Failure to do so may lead to an outcome as in the Canadian case of *Hawke v. Waterloo-Wellington Flying Club*,[312] where aircraft maintenance engineers who failed to exercise reasonable care towards maintaining accurate logbook records on airworthiness were found to have breached their duty of care.[313] The County Court of Ontario stated, "if reasonable care be not exercised, personal injury or property damage to the aircraft may reasonably be expected to follow."[314]

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309 *Tucker v McCann* [1948] VLR 222, 225 (Austl.) (explaining that breach of a statute will not necessarily be evidence of negligence).

310 *Civil Aviation Safety Regulations 1998* (Cth) pt. 101.340(1)(c)(i), (1)(e). *See supra* Section III.A.

311 *See* ADVISORY & DRAFTING BRANCH, LEGAL, INT'L & REGUL. AFFS. DIV., ss 10.07(1)(d), 10.12(2)(b) *(Unmanned Aircraft and Rockets) Manual of Standards 2019 (as amended)*, CIV. AVIATION SAFETY AUTH. (2020).

312 *See* Hawke v. Waterloo-Wellington Flying Club Ltd. et al. (1971), 22 D.L.R. 3d 266, 272–73 (Can. Ont. Co. Ct. J.).

313 *Id.* at 272–73.

314 *Id.* at 266.

In such cases, the standard of care to be applied is a professional one because engineers exercise special skill and expertise in their work.[315] This will be treated as a high standard by courts. For instance, in *Cifuentes*,[316] the court found that while an engineer advising on the design of a bearing was not considered to be high risk, the advice was central to the exercise of his expertise as an aeronautical engineer.[317] By providing negligent advice, his standard of care fell below that of a reasonable design engineer rendering him liable in negligence.[318]

Similar logic applied in *Aircraft Technicians of Australia Pty v. St. Clair*.[319] In that case, the plaintiff suffered an aircraft accident while mustering cattle in a Robinson R22 helicopter due to the failing of an upper actuator bearing.[320] The plaintiff filed a claim against the owner of the helicopter, Timtalla Pty Ltd, and against the operator, the Aircraft Technicians of Australia Pty Ltd (ATA).[321] The court found that ATA breached their duty when an employee, Mr. Fisher, installed an incorrect "NTN" bearing instead of a "Robinson" bearing.[322] The court determined that Mr. Fisher should have known from his training and qualifications that the features differed from a specially modified bearing as designated in a maintenance manual.[323] The manual also identified personal injury as a risk from failing to heed the warning against substitution, and Mr. Fisher's duty of care extended to investigating the provenance of the bearing.[324] Thus, his failure to do so constituted a breach of duty for ATA.[325]

In the above circumstances, on a practical level, a bearing monitoring device could have preemptively flagged the bearing issues before they led to a catastrophic failure. On a legal basis, the use of such a device could assist an operator in meeting the reasonable standard of care to ensure an airworthy drone. A log

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[315] *See Rogers v Whitaker* (1992) 175 CLR 479, 487 (Austl.) (explaining a similar principle of ordinary skills of practitioners in the context of medical expertise).

[316] *Cifuentes v Fugro Spatial Sols. Pty Ltd* [2009] WASC 316 (Austl.).

[317] *Id.* at para 296.

[318] *Id.* at paras. 289–296.

[319] *Aircraft Technicians of Austl Pty Ltd v St Clair; St Clair v Timtalla Pty Ltd* [2011] QCA 188 (Austl.).

[320] *Id.* at paras. 7–8.

[321] *Id.* at para. 1.

[322] *Id.* at paras. 93, 103.

[323] *Id.* at para. 102.

[324] *Id.*

[325] *Id.* at para. 103.

of the condition of the drone bearing could be adduced as evidence, and assuming the operator acted in a timely and reasonable manner based on any warnings, a plaintiff will find it more difficult to refute objective and technical evidence when asserting that operators breached their duty of care.

2. *Manufacturer*

A drone bearing monitoring device would also assist manufacturers in defending against a claim for breach of duty in negligence. A discussion on the liability of manufacturers under the Australian Consumer Law follows below. In the case of drones, ignoring the recommendations of CASA can provide evidence of not meeting the standard of a reasonable manufacturer. For example, CASA recommends that exteriors of drones have curvatures, that sharp protrusions be avoided, and that design areas should use energy absorbing materials.[326] However, by designing drones with in-built condition monitoring systems, manufacturers can turn CASA's attention to an internal design for safety. Manufacturers can demonstrate they have not only met the reasonable standard of care within the industry, but they have gone above the standard.

Presently, such technology is novel and unused, but arguably greatly needed.[327] Technical data on the reliability of drone hardware has suggested that RPA operations are most likely to experience loss of control in flight while cruising.[328] It is also cruising that poses the greatest danger to people or property on the ground, given the increase in elevation compared to take-off or landing and the drone's operation beyond visual line of sight.[329] It can be argued that a manufacturer that installs a real-time bearing monitoring device demonstrates an awareness and commitment to address the fundamental dangers that have been flagged by the literature.

Taking a step further, manufacturers that do not install such technology once it becomes widely available may find it more

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[326] AUSTL. CIV. AVIATION SAFETY AUTH. & MONASH UNIV., *supra* note 190, at 25 s 9.2.

[327] *See* Wild et al., *supra* note 35, at 8 (emphasizing the technology's stage of infancy).

[328] *Id.* at 9; *see generally* Bill Kaliardos & Beth Lyall, *Human Factors of Unmanned Aircraft System Integration in the National Airspace System*, *in* HANDBOOK OF UNMANNED AERIAL VEHICLES 2135 (Kimon P. Valavanis & George J. Vachtsevanos eds., 2015).

[329] *See* Kaliardos & Lyall, *supra* note 328, at 2138–40.

onerous to disprove a breach of duty. This is because certain functions of a drone (such as return to home) have matured to become industry standards, so bearing monitoring devices might eventually become one as well. This line of legal arguments has had success in the United States where failing to use appropriate technology can be classified as a breach of duty.[330] In the case *T.J. Hooper v. Northern Barge Corp.*, a tugboat operator was liable for not equipping his tugboat with radio equipment so that the crew could obtain current weather reports.[331] During this time, radio was beginning to proliferate into regular use by boats.[332]

It is noted, however, that proving breach and negligence or defect in high technology products is extremely challenging since it often requires expert witnesses, simulations, laboratory and flight tests, and extensive data analysis to succeed in a claim.[333] This may preclude most plaintiffs from running a case with the exception of class actions. However, with Australia's robust class action landscape in recent years,[334] there is nonetheless a legal rationale for manufacturers to fit their drones with functional bearing monitoring devices so that the argument of a drone having inadequate technology cannot be raised in the first place.

C. Causation

If breach is established, plaintiffs must then prove that the negligence caused their injuries (factual causation) and that it is appropriate to extend liability to the negligent party (legal causation).[335] In relation to causation, a drone bearing monitoring device can help track the chain of causation of an incident—identifying wherein the catastrophic failure, if any, occurred, and whether it was within the area of responsibility of the manufacturer, supplier, maintenance organization, operator, or other party.

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330 Perritt Jr., *supra* note 27, at 25.

331 T.J. Hooper v. N. Barge Corp., 60 F.2d 737, 740 (2d Cir. 1932).

332 Perritt, Jr., *supra* note 27, at 25.

333 *Id.* at 70.

334 Lauren Croft, *'Record' Number of Class Actions Filed in FY21*, LawyersWeekly (Sept. 26, 2021), https://www.lawyersweekly.com.au/biglaw/32592-record-number-of-class-action-filed-in-fy21 [https://perma.cc/R3CE-XKKE].

335 *Adeels Palace Pty Ltd v Moubarak* (2009) 239 CLR 420 paras. 41–45 (Austl.) (referring to *Civil Liability Act 2002* (NSW) s 5D(1) (Austl.)). The two-stage process is relevant at common law also. *See Pledge v Roads & Traffic Auth* (2004) 205 ALR 56, 59 para 10 (Austl.).

1. *Operator*

The impact of an RPA falling would be regarded as a necessary condition of causation of injury or property damage. A court would extend the scope of liability to damage caused by such an impact.[336] Even in situations where the damage to the plaintiff is indirect as in *Cook*—when the repairperson fell when attempting to repair the 22 kV conductor—the court has been willing to impute liability on the basis that "but for the impact of the aircraft on the conductor the plaintiff would not have been injured."[337]

Legal causation is a normative question which should be answered by a consideration of the "purpose" for which liability is sought to be imposed as well as relevant policy issues.[338] The argument that a technical fault of the bearing device amounts to a *novus actus interveniens* (an intervening act that breaks the chain of causation between the negligent act and the impact causing damage to person or property) is also unlikely to succeed unless a system fault is clearly not a causally independent event. Stewart opines that because common law principles focus on the risk created by the defendant's negligence and involve questions of "the very kind of thing likely to happen,"[339] liability will likely still be imposed.[340]

Another area of difficulty is in circumstances where there is an external interference (possibly with malicious intentions) where the operator was otherwise complying with regulations.[341] A drone's GPS may be attacked through "jamming" or "spoofing."[342] Jamming is when a strong interfering signal is transmitted that makes the drone unable to obtain its position.[343] Meanwhile, spoofing is when fake GPS signals are transmitted which cause the drone to think it is going in the correct direc-

336 Stewart, *supra* note 86, at 18–19.

337 *ACQ Pty Ltd v Cook; Aircair Moree Pty Ltd v Cook* (2009) 237 CLR 656, 665 para 27 (Austl.).

338 *Pledge*, 205 ALR at 59, para. 10; *Wallace v Kam* (2013) 250 CLR 375, para. 11 (Austl.).

339 *March v E & MH Stramare Pty Ltd* (1991) 171 CLR 506, 518 (Austl.); *Mahony v J Kruschich (Demolitions) Pty Ltd* (1985) 156 CLR 522, 529 (Austl.).

340 *See, e.g.*, *Allianz Austl Ins. Ltd. v GSF Austl Pty Ltd* (2005) 221 CLR 568, para. 65 (Austl.); *Travel Comp Fund v Tambree* (2005) 224 CLR 627, paras. 31–32 (Austl.).

341 *See* HODGKINSON & JOHNSTON, *supra* note 12, at 131.

342 Bharat Rao, Ashwin Goutham Gopi & Romana Maione, *The Societal Impact of Commercial Drones*, 45 TECH. SOC'Y 83, 86 (2016).

343 *Id.*

tion when, in fact, it is being misguided.[344] That is, the drone thinks it is in a location that it is not and so, heads in a direction other than that intended.[345] This direction would still be correctly deduced from the internal logic of the drone, but it would be based on incorrect inputs.[346] In this scenario, a drone crashing or causing damage as a result of the external interference of a third party raises novel legal questions. These include whether such an interference would warrant a break in the chain of causation and to what extent each party—the operator, owner, manufacturer, or malicious third-party (if they are even identifiable)—should be attributed liability in this instance.

These scenarios raise broader considerations of the operation of tortious liability and whether it is meeting the needs of a rapidly evolving society. The challenge of tort law is its focus on singular responsibility and its failure to properly address damage caused by systemic failure.[347] With today's context of "open" robotics, where an original product adopts a modular design comprising a combination of hardware or software, multiple independent parties can contribute to an incident.[348] This applies evidently to drones, which as robots, may be designed, "manufactured, assembled, programmed, owned, and operated by different legal persons."[349]

Academics have argued that "[e]xisting provisions of tort law may or may not include liability through remotely operated vehicles," which include "not only drones but also driverless cars and other vehicles."[350] In recent tort literature, in light of the rise of autonomous vehicles, Soh criticizes the continuing commitment to frame vehicle accident liability as driver-centric.[351] A similar logic persists in aviation, where following a crash, the focus of liability is generally first drawn to the pilot. Instead, Soh advocates that a control-centric approach to determining liability is not only possible but consistent with the tests for liability

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344 *See id.*

345 *See id.*

346 *See id.*

347 *See* Clarke & Moses, *supra* note 23, at 270.

348 *Id.*

349 *Id.*

350 Storr & Storr, *supra* note 74, at 118.

351 Jerrold Soh Tsin Howe, *Towards a Control-Centric Account of Tort Liability for Automated Vehicles*, SING. MGMT. U. 3 (2020), https://ink.library.smu.edu.sg/cgi/viewcontent.cgi?article=5174&context=sol_research [https://perma.cc/R6PJ-KA37] (published in Volume 26 of the Torts Law Journal).

and should be the preferred approach for autonomous vehicles.[352]

A control-centric approach can also reconcile the different meanings of control in the fields of engineering and law. In the engineering concept of control, "a 'controller' is said to control an object . . . only when the controller can make specific input choices that translate into the object exhibiting desired output behaviours."[353] In comparison, the legal definition of control is "concerned with the determination of the metaphysical risks of harm posed to society."[354] In tort law, "active physical control of the subject is neither necessary nor sufficient to constitute legal control; what matters is that the controller is in a position to determine the risks of harm the subject poses to society."[355] In the case of commercial aircraft, there has been a longstanding requirement to have a human pilot to pilot or, at the very least, to monitor the aircraft systems.[356] Even where functions on planes or autonomous drones are automated, the pilot or operator is still considered to be in legal control.[357]

However, a control-centric approach will mean that even though an autonomous vehicle is physically steered by software, legal persons across the supply chain including manufacturers, developers, operators, and consumers can all be said to be participants in the vehicle's risk creation process.[358] Each party can be said to have a degree of legal control and consequent legal liability.[359] Applying the same logic to drones will allow a plaintiff to pursue other defendants beyond just the operator in the scenario of defective or hijacked drones. While conventionally, the operator would have "legal control," with a control-centric analysis, it will be possible to trace liability back to novel defendants such as software developers who had negligently left vulnerabilities in their code or to manufacturers for hardware failures.[360]

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352 *Id.* at 3.

353 *Id.* at 15 (citing Bryant Walker Smith, *Lawyers and Engineers Should Speak the Same Robot Language* 78, 83 n.18, *in* ROBOT LAW (Ryan Calo, A. Michael Froomkin, & Ian Kerr eds., 2016)).

354 *Id.* at 16 (alteration in original).

355 *Id.* at 19 (alteration in original).

356 HODGKINSON & JOHNSTON, *supra* note 12, at 129.

357 Soh, *supra* note 351, at 19.

358 *Id.* at 20.

359 *Id.* at 4.

360 *See id.* at 25–26.

Throughout this exercise of tracing liability, a drone bearing monitoring device would provide valuable data in pinpointing or excluding fault of respective parties who are involved in bearing maintenance or manufacture. For example, the device may show that operators failed to conduct regular maintenance when required, making it easier to prescribe fault to them. Conversely, if the device detects that the underlying bearings were fully functioning, yet the drone still fell, this may point liability towards the software developers, a third-party interference, or perhaps a manufacturing defect caused by another piece of equipment on the drone.

These also raise important policy questions, such as what the threshold for a legally acceptable probability of detection of a bearing failure should be that—upon being met—would discharge the duty of care. Further nuances also need to be explored, such as if a bearing failure was determined as the cause of the accident or contributing to it, what liability would then flow to the monitoring system? Clearly such questions apply to every subsystem of the drone including, for instance, the navigation subsystem. Determining these standards of performance are important to enable the industry to evolve and for its benefits to be realized.

2. *Manufacturer*

For drone manufacturers, a control-centric approach would mean liability could be more readily established as fault and could be traced back to any potential defects in equipment, hardware, or software.[361] Establishing causation would be the primary hurdle to overcome in a claim against the manufacturer. In the case of a freight drone, it is likely to be operated semi-autonomously and be flying on pre-mapped routes as opposed to a pilot operating the drone within line of sight. This will also help to mitigate potential unfairness in a strict liability regime for RPAs where, for example, if a drone has defective software, instead of only the operator or pilot being held strictly liable,[362] the manufacturer or software developer could be traced to be a legal controller and held liable under negligence law.

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361 *See id.* at 20.

362 RON BARTSCH, JAMES COYNE & KATHERINE GRAY, DRONES IN SOCIETY: EXPLORING THE STRANGE NEW WORLD OF UNMANNED AIRCRAFT 91–92 (2017).

Whether a court or parliament adopts this approach in the future remains to be seen. As technologies like autonomous vehicles and drones propagate across society, the possibility of the law evolving to meet the literature's call to evolve from a driver-centric to a control-centric approach of tortious liability is certainly a possibility.[363]

D. Impact of Liability & Damages

An aggrieved plaintiff must show that he or she suffered a loss or damage in order to recover monetary compensation or "damages."[364] The award of damages could be either a combination of compensating the plaintiff (compensatory), acknowledging a breach of legal rights (nominal), or punishing the defendant (exemplary).[365] Usually for torts, damages are given on a compensatory basis, so plaintiffs are returned to their original position (restitutio in integrum).[366] Legislation in all jurisdictions confers on the courts a general power to award interest on damages for the period up to judgment.

There are two categories of damages: economic and non-economic loss, which are further split into separate heads of damage.[367] Economic losses include out-of-pocket expenses, lost wages, loss of earning capacity, and other needs created including medical or related bills.[368] These may need to be calculated for the rest of a person's life if the harm is permanent.[369] Non-economic loss relates to a plaintiff's capacity to enjoy life, encompassing physical pain and suffering, loss of amenities of life, and any shortening of life expectancy and disfigurement.[370] Legal costs of bringing actions can also be expensive, even though

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[363] Hodgkinson & Johnston, *supra* note 12, at 114; Roger Clarke, *Understanding the Drone Epidemic*, 30 Comput. L. & Sec. Rev. 230, 243 (2014); Kristiaan Bernauw, *Drones: The Emerging Era of Unmanned Civil Aviation*, *in* 66 Collected Papers of Zagreb Law Faculty 223, 244–45 (2016), http://hdl.handle.net/1854/LU-7279272 [https://perma.cc/2M7V-MR8L]; Kieran Tranter, *The Challenges of Autonomous Motor Vehicles for Queensland Road and Criminal Laws*, 16 QUT L. Rev. 59, 77–81 (2016).

[364] Perritt, Jr., *supra* note 27, at 51.

[365] *See XL Petroleum (NSW) Pty Ltd v Caltex Oil (Austl) Pty Ltd* (1985) 155 CLR 448, 471 (Austl.).

[366] *Todorovic v Waller* (1981) 150 CLR 402, 412 (Austl.).

[367] *See Sharman v Evans* (1977) 138 CLR 563; 13 ALR 57, 86 (Austl.).

[368] *See Medlin v State Gov't Ins Comm'n* (1995) 182 CLR 1, para. 2 (Austl.); *Wynn v NSW Ins Ministerial Corp* (1995) 184 CLR 485, para. 2 (Austl.).

[369] *See Sharman*, 13 ALR at 67; *Van Gervan v Fenton* (1992) 175 CLR 327; 109 ALR 283, 296 (Austl.).

[370] *Skelton v Collins* (1966) 115 CLR 94, 13 (Austl.); *Sharman*, 13 ALR at 63.

some cases are brought on a "no win-no fee" basis.[371] Generally, the rule in Australia is that costs are paid by the party who loses the case.[372]

The court gives parties an adequate opportunity to dispute the assessment if needed,[373] although many cases are settled earlier. Negligence requires proof of actual loss or injury to be proven, unlike trespassory torts.[374] Damages may be reduced where the plaintiff's unreasonable conduct before (contributory negligence) or after (failure to mitigate) suffering the injury contributes to the damage suffered or fails in whole or in part to alleviate it.[375]

1. Personal Injury

Traditionally, damages were assessed at the date of breach or when the cause of action arises, but courts have become increasingly flexible.[376] Personal injury is typically assessed on the date of the judgment to allow for a more accurate assessment after the court has evaluated all the evidence and the progress of the plaintiff's condition up to that time.[377]

Where there is permanent personal injury, the award of damages must account for the impossibility of being able to restore plaintiffs to their physical pre-injury position with compensation for the future consequences of the injury.[378]

2. Property Damage

Property damage torts usually do not involve complications of assessing future consequences. Awards usually fully compensate, although plaintiffs should reasonably mitigate any losses.[379]

Repairs may also be compensated so plaintiffs return to their pre-tort position. Where there is a difference in value, such as if repairs cost more than replacements, reasonableness will deter-

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371 *See generally "No Win-No Fee" Costs Agreements: Information for Consumers*, QUEENSLAND LEGAL SERVS. COMM'N (July 2021), https://www.lsc.qld.gov.au/__data/assets/pdf_file/0009/690543/no-win-no-fee-costs-agreement-july-2021.pdf [https://perma.cc/J99X-PTHF].

372 *See id.* at 1.

373 *Sharman*, 13 ALR at 65.

374 *See supra* Section V.D.

375 Dodd Props. (Kent) Ltd. v. Canterbury City Council [1979] 2 All ER 118 (QB) 125 (Eng.); Stewart, *supra* note 86, at 14.

376 *See Johnson v Perez* (1988) 166 CLR 351, 355–357 (Austl.).

377 *See id.* at 355–56.

378 *Todorovic v Waller* (1981) 150 CLR 402, 412–13 (Austl.).

379 Dodd Props. Ltd., 2 All ER at 128.

mine the end amount.[380] One scenario where this might be relevant is where a drone bearing fault causes the drone to fall which then causes fire damage to real property.[381] Often the issue will be whether damages should be valued at the cost of rebuilding or at the diminution in value.[382] Previously, courts have allowed the cost of rebuilding a family home to be compensated;[383] conversely, they have refused an investment property on the basis that plaintiffs could mitigate their damages by selling and then buying another property with the same investment return more cheaply rather than paying the more expensive cost of rebuilding.[384]

Where there is a net gain in the value of the property, the "betterment" may be reduced depending on the circumstances of the case. For example, courts have reduced damages in circumstances where an old tractor had caught on fire because the plaintiffs would have needed to purchase a new tractor later at some point anyways.[385] Conversely, where an old factory was burnt down, a defendant was required to pay the costs of a new factory as the owner would have continued to use the old factory had it not been destroyed.[386]

3. Multi-Party Liability

While Damage by Aircraft legislation imposes joint and several liability, in the common law, a plaintiff may need to rely on vicarious liability[387] or agency[388] to establish liability of the operator or owner who was not also the negligent pilot.

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380 *See Evans v Balog* [1976] 1 NSWLR 36, 40 (Austl.).

381 Thompson et al., *supra* note 28, at 4 para. 2.2.

382 *Evans*, 1 NSWLR at 40.

383 *Id.* at 41.

384 *Pantalone v Alaouie* (1989) 18 NSWLR 119, 137–38 (Austl.).

385 *See Hoad v Scone Motors Pty Ltd* [1977] 1 NSWLR 88, 93–94 (Austl.).

386 Harbutt's Plasticine Ltd. v. Wayne Tank & Pump Co. Ltd. [1970] 1 All ER 225 (Civ) 242 (Eng.).

387 *Hollis v Vabu Pty Ltd* (2001) 207 CLR 21, 23 (Austl.); *Stevens v Brodribb Sawmilling Co Proprietary Ltd* (1986) 160 CLR 16, 23 (Austl.) (whether there was an employer-employee or contracting relationship); *New South Wales v Lepore* (2003) 212 CLR 511, 517 (Austl.) (whether a teacher's improper punishment of a student was within scope of employment or an isolated incident of sexual assault); *Deatons Proprietary Ltd v Flew* (1949) 79 CLR 370, 376 (Austl.) (accepting the test that an employee acting deliberately or negligently within scope of authority holds the employer is liable).

388 *Scott v Davis* (2000) 204 CLR 333, 353 (Austl.); *Sweeney v Boylan Nominees Pty Ltd* (2006) 226 CLR 161 (Austl.) (discussing in depth the development of agency law).

Where two or more defendants are legally responsible for the same property damage or economic loss, statutory contribution and proportionate liability may apply.[389] If a defendant's tort has caused personal injury, death, or intentional property damage, he or she will have to pay a contribution.[390] Proportionate liability applies where property or economic loss was unintentionally caused and allows defendants to limit their damages to a fair and equitable portion in accordance with their responsibility for the harm.[391]

VI. PRODUCT LIABILITY UNDER THE AUSTRALIAN CONSUMER LAW

While negligence creates broad liability for actors, product liability focuses on responsibility of manufacturers for defective products. This can arise under the law of negligence as discussed above or pursuant to the Australian Consumer Law. "Product safety standards are a crucial aspect in the manufacture of drones."[392]

A plaintiff may pursue a statutory claim against the drone manufacturer under Schedule 2 of the *Competition and Consumer Act 2010* (Cth) or the Australian Consumer Law (ACL).[393] Under the ACL, there are now significant ramifications for aircraft manufacturers, creating a risk that must be recognized and managed.[394]

Liability is imposed on a strict liability basis where a manufacturer "supplies . . . goods in trade or commerce" with a "'safety defect' that causes injury."[395] A manufacturer includes any person who allows his or her business name, brand, or trademark to

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389 *Hunt & Hunt Laws v Mitchell Morgan Nominees Pty Ltd* (2013) 247 CLR 613, 619 (Austl.).

390 *See id.*

391 *Id.* at 625.

392 Storr & Storr, *supra* note 74, at 116.

393 *Competition and Consumer Act 2010* (Cth) sch 2 (Austl.). The Fair Trading laws of each State and Territory adopt Schedule 2 of the *Competition and Consumer Act 2010* (Cth) as the Australian Consumer Law. *Id.* The *ACL* applies to transactions occurring on or after January 1, 2011. *Id.*

394 For a discussion of how a case involving the supply of a defective bolt to a helicopter, causing rotor failure, would be decided differently today, see BARTSCH, *supra* note 91, at 495 (citing *Helicopter Sales (Aust) Pty Ltd v Rotor-Work Pty Ltd* (1974) 132 CLR 1 (Austl.)).

395 *See* FLEMING'S THE LAW OF TORTS, *supra* note 275, at 573; *ACL, supra* note 393, at s 138(1).

be applied to the good,[396] but also includes "manufacturers of component parts, maintenance organizations, distributors, second-hand dealers,"[397] and importers if the manufacturer has no place of business in Australia.[398] Goods include "aircraft and other vehicles,"[399] and a safety defect is where "their safety is not such as persons generally are entitled to expect."[400] This is an objective standard based upon what the public at large would expect.[401] A good can generally be defective from negligence in the process of its manufacture, design, or marketing.

A. Defective Manufacture

Defective manufacture or production defects refer to products that are deviants from the manufacturer's specifications in their construction or assembly.[402] Where the plaintiff establishes the existence of a defect in the product and an accompanying injury, the court will infer liability unless the manufacturer can prove the defect was not present at the time it supplied the goods.[403] In the event of a bearing failure, a bearing monitoring device with data-recording functions would be helpful to a manufacturer as it could provide a history of data that the drone bearing was functional from its inception and free of production defects.

B. Defective Design

Defective designs relate to such elements as the form, structure, and composition of goods.[404] However, this is a more complex action as design decisions are often conscious choices by the manufacturer after weighing up relative cost, consumer

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396 *Competition and Consumer Act 2010* (Cth) s 7(1)(c) (Austl.); *see Glendale Chem Prods Pty Ltd v Austl Competition & Consumer Comm'n* (1998) 90 FCR 40, 44 (Austl.).

397 Bartsch, *supra* note 91, at 184.

398 *Competition and Consumer Act 2010* (Cth) s 7(1)(e) (Austl.).

399 *Id.* at s 2(1). Computer software is also included. *Id.* This is relevant because software flies aircraft. Fleming's The Law of Torts, *supra* note 275, at 578.

400 *Competition and Consumer Act 2010* (Cth) s 9(1) (Austl.).

401 *Carey-Hazell v Getz Bros & Co (Austl) Pty Ltd* [2004] FCA 853, para 186 (Austl.); *Glendale Chem Prods Pty Ltd v Austl Competition & Consumer Comm'n* (1998) 90 FCR 40, 47 (Austl.).

402 Fleming's The Law of Torts, *supra* note 275, at 557.

403 *Id.* at 574; *Competition and Consumer Act 2010* (Cth) s 142(a)(ii) (Austl.); *Carey-Hazell*, [2004] FCA at paras 190-91; *Effem Foods Ltd v Nicholls* [2004] NSWCA 332, para. 17 (Austl.).

404 Mabel Tsui, *The State of the Art Defence: Defining the Australian Experience in the Context of Pharmaceuticals*, 13 QUT L. Rev. 132, 134 (2013).

preferences, or even public interest (for example, delivery drones that are smaller and less safe but quieter, cheaper, or more environmentally friendly). Academics have pointed out that judiciaries are ill-equipped to deal with such polycentric issues and their implications.[405] There is additional difficulty in actually determining whether a drone's design is defective as currently no specific airworthiness standards to compare against exist.[406] Courts will need to consider the risk of harm against the cost of reducing it by adopting an alternative design. Installing a drone with a bearing monitoring device would reduce its risk of harm and likewise afford it greater protection to a defective design claim.

C. Defective Marketing

Defective marketing includes instructional defects such as insufficient labelling, warnings, or instructions.[407] This may be relevant in scenarios where a drone manufacturer or supplier faces a lawsuit alleging that the drone would not have fallen to the ground if the instructions or warnings regarding the airworthiness of the drone were adequate. However, it is often difficult to ascertain the known risks of a product, which is especially the case with new technologies such as drones.[408] Further, in the case of commercial delivery drones, which are more complex than hobbyist drones, it is likely that specialized training would be required to use them. In any case, however, manufacturers will still need to ensure sufficient instructions are provided to operators on not just general drone usage but also on the strict maintenance that is required. While a bearing monitoring device helps in this regard by flagging potential airworthiness issues, to minimize legal liability, the manufacturer should also instruct that the device cannot be relied upon exclusively.

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[405] Fleming's The Law of Torts, *supra* note 275, at 559; Lon L. Fuller & Kenneth I. Winston, *The Forms and Limits of Adjudication*, 92 Harv. L. Rev. 353, 394–95, 400 (1978) ("Generally . . . problems in the allocation of economic resources present too strong a polycentric aspect to be suitable for adjudication.").

[406] In the United States, this normally involves a "risk-utility" test. *See* Kristopher-Kent Harris, *Drones: Proposed Standards of Liability*, 35 Santa Clara High Tech. L.J. 65, 85 (2018).

[407] *Glendale Chem Prods Pty Ltd v Austl Competition & Consumer Comm'n* (1998) 90 FCR 40, 46 (Austl.).

[408] Harris, *supra* note 406, at 90.

D. Consumer Rules

An additional source of liability specific to freight drones comes from consumers. The ACL imposes minimum standards in relation to commercial services provided to consumers, which will apply to RPA deliveries.[409] A Commonwealth Minister can also issue a mandatory set of specific safety standards of delivery services.[410] Where commercial drone operators contravene the safety standards, they can be liable for a penalty for any loss suffered as a consequence of the breach.[411] Currently, no ministerial safety standards have been imposed for RPA delivery; however as adoption grows, such standards can be expected to be issued.

E. Damages

Those who suffer personal injury (or death)[412] and damage to goods,[413] including land and fixtures,[414] can sue the manufacturer for damages under consumer law. Third parties who suffer loss due to injuries caused by a defective product can also recover damages.[415] This includes dependents reliant upon the injured person and potentially bystanders who suffer emotional harm from witnessing the injury.[416] A three-year limitation period applies from the time the claimant became, or ought to have become, aware of the damage and identity of the manufacturer.[417]

In relation to defenses, where the manufacturer of a drone is independent from a bearing monitoring device's manufacturer, under the ACL, component manufacturers have a defense if they can establish that the defect is attributable to the design, markings, instructions, or warnings of the finished good—rather than a defect in the component.[418] Other than this, because manufacturers are held strictly liable for defective products, there is a clear legal impetus for manufacturers to focus on

409 *Competition and Consumer Act 2010* (Cth) s 104(3) (Austl.).
410 *Id.* at ss 104–08, 194–96.
411 *Id.* at s 107.
412 *Id.* at s 138(3).
413 *Id.* at s 40.
414 *Id.* at ss 140–41.
415 *Id.* at s 139.
416 *Erwin v Iveco Trucks Austl Ltd* (2010) 267 ALR 752, 784 (Austl.).
417 *Competition and Consumer Act 2010* (Cth) s 143(1) (Austl.); *see also* Consumer Protection Act 1987 § 6(6) (UK).
418 *Competition and Consumer Act 2010* (Cth) s 142(d) (Austl.).

preventing the drone from falling in the first place using diagnostic or early warning systems such as bearing monitoring technology.

VII. RESPASSORY TORTS

Trespassory torts are actionable per se, meaning that proof of pecuniary loss or injury is not necessary.[419] Rather, the law seeks to recognize that a plaintiff's absolute right has been violated.[420] Nonetheless, evidence of a specific loss is still generally required; otherwise the award is only for a token sum of nominal damages.[421]

In relation to trespassory torts, the key benefit of a drone bearing condition monitoring system is the improvement to drone airworthiness, lowering the chance of a catastrophic failure causing the drone to fall to the ground and cause an act of trespass to occur.

A. Trespass to Land

In aviation cases, trespass to land often relates to surface damage caused by chattels falling from aircraft or damage by the aircraft itself.[422] A drone or its freight falling to a plaintiff's land can constitute trespass to land.

This requires a positive, voluntary act that directly interferes with the plaintiff's exclusive possession of his or her land.[423] In this case, the drone pilot's or operator's act of controlling the drone to enter the land would be adequate.[424] Intention is necessary to establish trespass to land, although a reckless or negligent act is adequate.[425] The defendant has the onus of proving the absence of intention.[426]

The act of interference must be direct and not consequential.[427] For example, courts have held an oil spill discharged into

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419 *LJP Invs v Howard Chia Invs Pty Ltd* (1989) 24 NSWLR 490, 496 (Austl.).

420 *See id.* at 497.

421 *Id.* at 496.

422 Bartsch, *supra* note 91, at 212.

423 Stewart, *supra* note 86, at 25.

424 *Pub Transp Comm'n (NSW) v Perry* (1977) 137 CLR 107, para. 8 (Austl.); Stewart, *supra* note 86, at 25.

425 League Against Cruel Sports Ltd. v. Scott [1985] 2 All ER 489 (QB) 494, [1986] 1 QB 240 (Eng.).

426 *See, e.g.*, *McHale v Watson* (1964) 111 CLR 384, 384 (Austl.).

427 Southport Corp. v. Esso Petrol. Co. Ltd. (1954) 3 WLR 200, [1954] 2 All ER 561 (Civ) 561–62 (Eng.).

an estuary that was then carried onto the plaintiff's land by the river to be a consequential interference.[428] The distinguishing factor is how closely related the act is with the interference.[429] If a significant passage of time elapses, it may lead to a consequential rather than immediate and direct finding.

Where a bearing condition sensing device is relevant is when the device indicates that due to bearing failure, a drone should either land immediately or hover to a lower altitude over the neighborhood, which in turn causes an interference with a landowner's property rights. While this may not be an issue for the recipient of the delivery parcel (in a similar way to how implied consent is given to postage carriers to enter land for the purpose of delivering a parcel) a disgruntled neighbor may take issue with the unwarranted trespass. In this scenario, assuming the landowner has sufficient title to sue, whether a claim of trespass will succeed will depend on the circumstances and extent of the interference.[430]

Where the drone or cargo falls to the ground, and there is a clear, direct, and obvious physical interference with the surface of the land, it is likely that the above elements for a trespass to land will be made out. If, however, there is only a mere overflight over property, for example, as the RPA descends to a lower altitude to prevent further bearing deterioration, it will be a much more complex determination.

The issue of trespass into airspace by an overflying aircraft has not been dealt with in Australia; however, the principles from overseas jurisdictions have been tested and approved in Australian courts.[431] In *LJP Investments v Howard Chia Investments Pty. Ltd.*,[432] Justice Hodgson approved the view from the English case *Bernstein of Leigh v. Skyviews & General Ltd. (Bernstein)*[433] that a landowner's right to the air space above his property is limited to "such height as is necessary for the ordinary use and enjoy-

[428] *Id.*

[429] *Id.* at 562.

[430] *See Newington v Windeyer* (1985) 3 NSWLR 555, 559 (Austl.).

[431] *LJP Invs Pty Ltd v Howard Chia Invs Pty Ltd* (1989) 24 NSWLR 490, 495 (Austl.); *see also Bendal Pty Ltd v Mirvac Project Pty Ltd* (1991) 23 NSWLR 464, 465 (Austl.); *Break Fast Invs Pty Ltd v PCH Melbourne Pty Ltd* (2007) 20 VR 311, para 49 (Austl.) (dealing with a physical encroachment rather than an aircraft encroachment onto property).

[432] *LJP Invs*, 24 NSWLR at 495.

[433] Bernstein of Leigh v. Skyviews & Gen. Ltd. [1977] 3 WLR 136 (QB) (Eng.).

ment of his land and the structures upon it."[434] In *Bernstein*, the defendant company Skyviews took a single aerial photograph from a plane while flying over the plaintiff's country residence.[435] The plaintiff claimed his right to exclude any entry into the airspace above his land.[436] The court held that a landowner's rights do not extend to unlimited heights and are limited to the height of an "ordinary user."[437]

However, it is unsettled whether the same outcome will be reached upon application to drones. Stewart contemplates that the liability of RPAs may be ruled differently today given *Bernstein* was decided in 1978 and concerned solely with flights by planes.[438] In *Bernstein,* Justice Griffiths found a flight of several hundred feet above the ground to not be a trespass because there was no real interference with the landowner's use of his land.[439] However, the flight height of a delivery drone is substantially lower than that of a plane, especially during the actual descent of the delivery.[440] In Australia, trespasses to land have previously been found where crane jibs intruded at heights of fifty feet above the plaintiff's roof.[441] It also does not matter if the trespasses are not continuing. Even irregular or intermittent intrusions can be sufficient for an action. In *Graham v KD Morris & Sons Pty Ltd*,[442] wind causing a crane jib to extend sixty-two feet above an adjoining land was held to be a trespass to land.

The counterargument is that the formulation of the *Skyviews* test should be understood in the context of a case about a mere entry into airspace as distinct from an intrusion by something erected on other land (i.e., the encroaching crane cases litigated in Australia). In the United States, there is authority that actual overflight must have occurred at a height which adversely affects the use and enjoyment of the surface to the extent to

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434 *Id.* at 141 (rebutting the old Roman maxim *cujus est solum ejus est utque ad coelum et ad inferos*—that whoever owns the soil owns all that lies above it).

435 *Id.* at 137.

436 *Id.* at 138.

437 *Id.* at 140.

438 Stewart, *supra* note 86, at 24–25.

439 *Bernstein*, 3 WLR at 141.

440 Stewart, *supra* note 86, at 25.

441 *LJP Invs Pty Ltd v Howard Chia Invs Pty Ltd* (1989) 24 NSWLR 490, 495 (Austl.); *Graham v KD Morris & Sons Pty Ltd* [1974] Qd R 1, 2 (Austl.); *Bendal Pty Ltd v Mirvac Project Pty Ltd* (1991) 23 NSWLR 464, 466 (Austl.).

442 *Graham*, [1974] Qd R at 2, 4; *see also* Woollerton & Wilson Ltd. v. Richard Costain Ltd. [1970] 1 All ER 483 (Ch) 484 (Eng.) (English case preceding *Graham*).

devaluing the property's value.[443] Additionally, some academics have pointed out the difficulties of the alternative view, as it would "involve the courts in the impossible task of trying to determine whether there has been an invasion of a particular column of airspace."[444]

Thus, it seems so long as the RPA flies above the height of an ordinary user, it would not commit a trespass to land. As Butler points out, drones may operate at heights well above sixty-two feet, as recognized by CASA's standard RPA operating conditions which stipulate operation at a height of up to four hundred feet above ground.[445]

B. Trespass to Persons

Where the RPA collides with a person, or a part of the RPA falls and causes damage, a cause of action in battery can arise. The plaintiff is required to prove that the defendant committed an intentional, positive, voluntary act which directly caused contact with the plaintiff's body.[446] A battery is actionable per se without proof of damage.[447]

A collision does not have to be a deliberate act; recklessness is adequate to suffice as intention.[448] A negligent act can also enable a claim in battery in Australia.[449] State civil liability would then apply.[450]

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[443] United States v. Causby, 328 U.S. 256, 266 (1946). The U.S. Supreme Court found that government aircraft frequent flying so low as to make the land unusable amounts to an unconstitutional "taking" of property within the meaning of the Fifth Amendment. *Id.* at 258, 266. Subsequent decisions confirmed overflight as well as a reduction in property value is necessary for there to be an unconstitutional taking. *See* Griggs v. Allegheny Cnty., 369 U.S. 84, 90 (1962); Batten v. United States, 306 F.2d 580, 585 (10th Cir. 1962).

[444] Margaret Lee, *No Noise Is Nice*, 9 Victoria U. Wellington L. Rev. 165, 177 (1978).

[445] Butler, *supra* note 83, at 1043.

[446] *Sec'y, Dep't of Health & Cnty Servs v JWB [Marion's Case]* (1992) 175 CLR 218, 311 (Austl.).

[447] Cole v. Turner (1704) Eng. Rep. 958, 958; 6 Mod Rep 149.

[448] James v. Campbell (1832) Eng. Rep. 1015, 1015; Ball v. Axten [1866] Eng. Rep. 2, 176 ER 890 (QB) 891 (Eng.); *see* Francis Trindade, Peter Cane & Mark Lunney, The Law of Torts in Australia 41 (4th ed. 2007).

[449] *See* Stewart, *supra* note 86, at 23.

[450] *Civil Liability Act 2002* (NSW) s 3B (Austl.); *Civil Liability Act 2002* (Tas) s 3B (Austl.); *Wrongs Act 1958* (Vic) s 28C (Austl.); *Civil Liability Act 2002* (WA) s 3A (Austl.). Some State jurisdictions do not exclude deliberate acts. *See Civil Liability Act* 2003 (Qld) s 5 (Austl.); *Civil Liability Act 1936* (SA) s 4 (Austl.); *Civil Law (Wrongs) Act 2002* (ACT) s 141(b) (Austl.) (covering negligent trespass of land); *Personal Injuries (Liabilities and Damages) Act 2003* (NT) s 4 (Austl.).

In relation to directness, Stewart contemplates that like how firing a gun or throwing a missile at another constitutes a battery, an RPA pilot controlling a machine that impacts another would satisfy the directness element.[451]

The key advantage to plaintiffs is they do not need to prove fault. As Stewart points out, "[a] person injured by an RPA falling from the sky will possibly have scant evidence as to the cause of the event, though negligence of the operator would be a likely cause."[452] For trespass to person, however, once the trespassory contact is established, the onus shifts to the defendant to prove lack of fault to escape liability.[453] In that case, any available data readings of a drone bearing monitor could potentially be adduced by an operator to show that the crash was not the result of a catastrophic failure from the bearing or any other maintenance problem which falls under the operator's responsibility. In this way, the device can potentially help ground an argument in redirecting or narrowing fault to other causes.

However, the success of this argument will depend on the data of the respective monitoring device records. At the bare minimum, a device recording just the immediate data surrounding a warning signal would help in verifying the operation of the monitoring system and confirm the accuracy of its determination. On the other hand, a device that records all the real-time data, beyond just the condition of a bearing, would provide the most legal benefit in demonstrating where fault occurred (although such capabilities would likely cost more).

C. Trespass to Goods

Where a drone either lands or crashes into a plaintiff's goods (such as a car), the operator can be liable to an action for trespass to goods. Trespass to goods involves the intentional or negligent act of the defendant which directly interferes with the plaintiff's possession of a chattel without lawful justification.[454] The plaintiff must be able to show he or she was in possession of the goods at the time of the act of interference by the defendant.[455]

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451 Stewart, *supra* note 86, at 23; *McHale v Watson* (1964) 111 CLR 384, 389 para. 9 (Austl).

452 Stewart, *supra* note 86, at 23.

453 *See McHale*, 111 CLR at 389 para. 20.

454 *Penfolds Wines Pty Ltd v Elliott* (1946) 74 CLR 204, 214–15 (Austl.).

455 *Id.* at 216.

Plaintiffs will have a duty to mitigate their damages. For example, for mass-produced goods, it is expected that plaintiffs replace their goods if repairing it would cost more.[456] However, a more expensive repair job has been permitted by courts, such as in the case of a car with sentimental value.[457] Like other trespassory torts, the determinative factor will be evidence of reasonableness.[458]

Again, the bearing monitoring device will help with preventing the trespass from occurring to begin with, or it will forewarn of a danger of catastrophic failure early enough for the drone to be able to land safely at a significantly lower velocity than falling out of the sky.

VIII. NUISANCE

In addition to improving the airworthiness of the drone, a drone-bearing monitoring system can also help prevent or rebut a claim in nuisance. A condition monitoring device can provide evidence that the motor bearing is healthy and operating normally. It can then be deduced that the bearing is not causing the drone to vibrate excessively and that any audible noise generated by the propulsion system should be within typical operating limits.

There are two types of torts based in nuisance: "Private nuisance concerns a nuisance to the private rights of an individual, specifically those concerning their use and enjoyment of land; and public nuisance concerns interference with those interests that are shared by the public."[459] Unlike trespass to land, a nuisance may be caused by an indirect act of interference, and thus includes intangible invasions such as noise, smell, and offensive sights, in addition to more tangible invasions such as fire, leaves, flood, and dust.[460] A plaintiff may also prefer to run a claim in nuisance because, unlike negligence, defendants cannot avoid liability by demonstrating they exercised reasonable care while

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[456] Harbutt's Plasticine Ltd. v. Wayne Tank & Pump Co. [1970] 1 All ER 225 (Civ) at 240 (Eng.).

[457] O'Grady v. Westminster Scaffolding Ltd. (1962) 2 Lloyd's Rep. 238 (QB) at 240 (Eng.).

[458] *Murphy v Brown* (1985) 1 NSWLR 131; 2 MVR 29, 31–32 (Austl.).

[459] CAROLYN SAPPIDEEN, PRUE VINES & PENELOPE WATSON, TORTS: COMMENTARY AND MATERIALS 753 (11th ed. 2012).

[460] *See* Osborne M. Reynolds, *Distinguishing Trespass and Nuisance: A Journey Through a Shifting Borderland*, 44 OKLA. L. REV. 227, 231–33 (1991).

performing their duty of care.[461] Thus, as Quinlivian explains in a hypothetical scenario, if a properly trained operator flies a well-maintained drone over a worksite, and the drone is struck by a large bird rarely seen in the area, causing a crash and damage to the property—while the operator could likely defend an action in negligence due to the reasonableness of his or her actions—the worksite owner may succeed with a claim in nuisance.[462]

In the case of a drone delivery, the relevant claim would most likely be one in private nuisance from somebody who has found the peaceful enjoyment of his or her land disturbed by the RPA in some way. Some authority suggests that actions in nuisance against aircraft operators could lie in cases of excessive noise, vibration, or pollution which seriously interfere with a plaintiff's enjoyment of his or her property.[463] In regard to Wing's operations in Canberra, it has been reported of "dogs going wild," "children being too scared to play in backyards due to the racket," and "birds disappearing from the area."[464] However, as these are only media reports, any legal claim will need to examine the specific facts of the case.

The court will weigh the nature and circumstances of the defendant's activity and the character of the resulting interference against the plaintiff's interest.[465] The factors that comprise this "give and take" equation include the duration,[466] time of day,[467] frequency,[468] locality,[469] and the extent of the interference. While a temporary interference will not preclude it from being a material interference, generally it will not qualify as a nui-

[461] Peter Quinlivian, *Airborne Effrontery: Dealing with an Unwanted Drone Over-Flight Under Australian Law*, 9 INT'L IN-HOUSE COUNS. J. 1, 5–6 (2016).

[462] *Id.* at 6.

[463] Bernstein of Leigh v. Skyviews & Gen. Ltd. [1977] 3 WLR 136 (QB) 143 (Eng.); Steel-Maitland v. British Airways Bd. (1981) Scots LT 110, 111–12 (Scot.).

[464] Kate Christian & Craig Allen, *'Territorial' Ravens Disrupt Surge in Wing Drone Deliveries Under Canberra's Lockdown*, ABC NEWS, https://www.abc.net.au/news/2021-09-22/territorial-ravens-disrupt-canberra-drone-deliveries/100480470 [https://perma.cc/3REP-5V2X] (Dec. 9, 2021, 6:27 PM).

[465] *See Munro v S Dairies Ltd* [1955] VLR 332, 337 (Austl.).

[466] *See* Andreae v. Selfridge & Co. [1938] Ch 1 (CA) 4 (Eng.) (discussing noise "resulting from temporary and lawful work carried out with reasonable care and skill").

[467] *McKenzie v Powley* [1916] SALR 1, 17–18 (Austl.).

[468] *Seidler v Luna Park Rsrv Tr* (Unreported, Supreme Court of New South Wales Equity Division, Hodgson J, 21 September 1995) 31 (Austl.).

[469] Sturges v. Bridgman (1879) 11 Ch D 852, 865 (Eng).

sance.[470] Further, akin to trespass to land on the basis of *Bernstein*, mere overflight will not be considered a nuisance.[471] The plaintiff will need to prove some sort of constant and continuing interference or harassment.[472] Wing has argued that their deliveries are infrequent and cited that it is "unlikely people will experience considerable or repeated noise events during the hover phase, as it is limited to the immediate vicinity of the delivery location."[473] Wing has also pointed out that drones differ from crewed aircraft in landing or take off, being much quieter and taking place in significantly shorter windows of time.[474]

However, a bearing problem can lead to an increase in audible noise which may potentially lead to a violation of legal noise limits in certain areas. Wing has previously received complaints about their drone noise levels and was forced to re-engineer their drones as a result.[475] Wing has now stated that, when hovering to deliver, their drones are the same noise level as an ordinary cruising car and quieter than most common neighborhood noises, such as a leaf blower or lawnmower.[476] However, it has also been pointed out that the noise is more noticeable since it is a high frequency pitch that suburban environments have not previously experienced.[477] Consequently, there is still potential for delivery drones to be vulnerable to legal arguments of nuisance. This provides a strong incentive for operators to install bearing monitoring devices to prevent any further amplifications of audible noise or vibration arising from bearing fatigue.

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470 *See* Bernstein of Leigh v. Skyviews & Gen. Ltd. [1977] 3 WLR 136 (QB) 143 (Eng.).

471 *Id.* at 141.

472 *See id.* at 143.

473 Wing Aviation Pty Ltd, Submission No. 35 to Austl. Dep't of Infrastructure, Transp., Cities & Reg'l Dev. (Nov. 19, 2019), *in* REVIEW OF THE AIR NAVIGATION (AIRCRAFT NOISE) REGULATIONS 2018 – REMOTELY PILOTED AIRCRAFT 5–6 [hereinafter Wing Submission No. 35], https://www.infrastructure.gov.au/sites/default/files/migrated/aviation/environmental/aircraft-noise/files/035_Wing_RPA_submission_ATT.pdf [https://perma.cc/F2PQ-EUZN].

474 *Id.* at 10.

475 Stuart Layt, *Drone Delivery Service Wing Launches Less Noisy Drones to More Suburbs*, BRISBANE TIMES (May 26, 2021, 12:01 AM), https://www.brisbanetimes.com.au/national/queensland/drone-delivery-service-wing-launches-less-noisy-drones-to-more-suburbs-20210525-p57v3p.html [https://perma.cc/2TEX-UPKN].

476 Wing Submission No. 35, *supra* note 473, at 5–6.

477 Jackson Gothe-Snape, *Google-Affiliated Drone Delivery Service Found to Be Exceeding Noise Limits*, ABC NEWS, https://www.abc.net.au/news/2019-09-12/canberra-delivery-drone-noise-levels-revealed/11503262 [https://perma.cc/T4B2-SGV6] (Nov. 20, 2019, 12:10 AM).

IX. PRIVACY AND SURVEILLANCE ISSUES

While the focus of regulations has been concerned with safety, if delivery drones proliferate, the companies behind them will be running substantial operations over private, residential areas. This may be a relevant factor where a bearing condition sensing device indicates a drone needs to land immediately, causing the drone to descend over someone's property while it continues to record footage. This could constitute an interference with an individual's privacy rights, especially where an operator manually begins to pilot the delivery drone through the camera.

Unlike many other jurisdictions, the *Privacy Act 1988*[478] in Australia does not provide an extensive framework to protect privacy. The House of Representatives Standing Committee report noted the privacy law "is not intended to protect against intrusions into Australians' private seclusion."[479] Without any legal remedy under Australian privacy law, the affected individual or entity can only report the matter to CASA.[480]

Surveillance prohibition legislation is also likely ineffective, as other than drones not being the target of the legislation, "private activities" expressly do not include any activity carried on outside a building.[481] This would preclude the majority of RPA activity from being captured by the legislation.

Criminal law may provide an indirect form of privacy protection. Certain drone operations may satisfy offenses in some jurisdictions, for example under the offense of voyeurism. In the United States, there are laws relating to trespass, privacy, and stalking, in addition to state-specific laws regulating paparazzi and anti-voyeurism. Some states such as Indiana and Florida have enacted drone laws with voyeurism offenses.[482] Nonetheless, perhaps the more significant issue is that it is doubtful these laws will apply to freight drones in the first place (given their

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[478] *See generally Privacy Act 1988* (Cth) (Austl.).

[479] AUSTL. H.R. STANDING COMM. ON SOC. POL'Y & LEGAL AFFS., EYES IN THE SKY: INQUIRY INTO DRONES AND THE REGULATION OF AIR SAFETY AND PRIVACY 35 para. 4.12 (2014).

[480] Quinlivian, *supra* note 461, at 2.

[481] *Id.* at 3 (referring to *Surveillance Devices Act 1999* (Vic) s 3 (Austl.)).

[482] *See generally* HODGKINSON & JOHNSTON, *supra* note 12, at 33; *see also* Jessica Schladebeck, *Utah Couple Charged with Voyeurism for Allegedly Recording Unsuspecting People with Drone*, N.Y. DAILY NEWS (Feb. 16, 2017, 9:13 AM), https://www.nydailynews.com/news/crime/couple-charged-voyeurism-recording-people-drone-article-1.2974236.

distinct purpose is delivery operations. In Australia especially, given Australia's relatively weak protection of privacy, the installation of bearing condition-sensing devices and accompanying cameras on drones does not immediately raise any litigable issues.[483]

X. BREACH OF STATUTORY DUTY

The breach of a duty imposed by a statute can give rise to a claim under the tort of breach of statutory duty.[484]

This is advantageous for a plaintiff to argue as it is a strict liability offense. However, the courts have generally restricted this action to worker safety and similar matters so it may not be regarded as valid.[485] Rather, as discussed above, a breach of statutory duties may just be used as evidence in a claim of negligence that a person has fallen short of the care expected of a reasonable person compliant with regulations.[486]

XI. DEFENSES

On top of the defenses discussed above in each cause of action, certain state and territory civil liability legislations relating to defenses apply because they are expressed to apply to "civil liability of any kind."[487]

A. Good Samaritans

In all jurisdictions, there are provisions that protect community volunteers from liability.[488] These provisions would protect RPA pilots and operators from liability under *Damage by Aircraft* legislation (and at common law) if they were engaged in unpaid volunteer or rescue efforts.

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483 In Australia, voyeurism is an offence under state criminal codes. *See, e.g.*, *Criminal Code Act 1899* (Qld) s 227A (Austl.); *Crimes Act 1900* (NSW) s 91J (Austl.).

484 *Stuart v Kirkland-Veenstra* (2009) 237 CLR 215, 263 para. 140 (Austl.).

485 *See* Stewart, *supra* note 86, at 21.

486 *O'Connor v SP Bray Ltd* (1937) 56 CLR 464, 477 (Austl.).

487 Stewart, *supra* note 86, at 15.

488 *Civil Law (Wrongs) Act 2002* (ACT) s 5 (Austl.); *Civil Liability Act 2002* (NSW) s 57 (Austl.); *Personal Injuries (Liability and Damages) Act 2003* (NT) s 8 (Austl.); *Civil Liability Act 2003* (Qld) ss 26–27 (Austl.); *Civil Liability Act 1936* (SA) s 74 (Austl.); *Civil Liability Act 2002* (Tas) s 35B (Austl.); *Wrongs Act 1958* (Vic) s 31B (Austl.); *Civil Liability Act 2002* (WA) s 5AD (Austl.).

B. Intoxication

In NSW, a statutory defense is available where persons are intoxicated at the time of their injury. The provision applies to "civil liability of any kind for personal injury damages."[489]

In other states, there is a presumption of contributory negligence where a plaintiff is intoxicated; those provisions apply to claims for personal injury[490] or to proceedings for recovery of damages.[491]

C. Illegality

Some state and territory provisions allow a type of illegality defense,[492] which limits the recovery of damages in civil claims by persons if they were engaged in criminal conduct at the time of injury.

XII. CONCLUSION

In today's age of robots, automation, and innovation, the rising wave of new use cases for drones has also generated new scenarios involving a range of technical, operational, and legal issues. Drone delivery shows particular promise in transforming the freight and retail sector by expanding the reach or sales of local businesses, lowering costs for consumers, and reducing greenhouse emissions and accidents on the road. However, there is a concern that accidents from the sky will emerge in their place. With equipment failure currently accounting for the majority of drone incidents, motor bearing issues present significant risks for operators and manufacturers as bearing failures are the most common cause of motor failure. Currently, there is a continuous danger that the attrition of the drone bearing may cause a catastrophic failure, leading the aircraft to fall to the ground and cause bodily injury, damage to goods, or trespass to property. While this issue has received some attention in the en-

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489 *Civil Liability Act 2002* (NSW) s 47 (Austl.).

490 *Civil Law (Wrongs) Act 2002* (ACT) ss 93, 95 (Austl.).

491 *Civil Liability Act 2002* (WA) s 5L(1) (Austl.); *Personal Injuries (Liability and Damages) Act 2003* (NT) ss 14–17 (Austl.); *Civil Liability Act 1936* (SA) ss 46–48 (Austl.); *Civil Liability Act 2002* (Tas) s 5 (Austl.). In Queensland and Victoria, the provision applies only in the case of a breach of duty. *Civil Liability Act 2003* (Qld) ss 46–49 (Austl.); *Wrongs Act 1958* (Vic) s 14G (Austl.).

492 *Civil Law (Wrongs) Act 2002* (ACT) ss 93–94(1) (Austl.); *Civil Liability Act 2002* (NSW) ss 51, 54 (Austl.); *Personal Injuries (Liabilities and Damages) Act 2003* (NT) s 10(1) (Austl.); *Civil Liability Act 1936* (SA) s 43(1) (Austl.); *Civil Liability Act 2002* (Tas) ss 5A–6 (Austl.).

gineering field, so far it has remained unaddressed in the legal scholarship. This Article has sought to address this research gap by investigating how a drone bearing condition monitoring system can mitigate against liability for freight drones. It has been argued that there is a strong legal rationale for the installation of such a device.

First, in relation to safety regulations of freight drones, a reliable drone bearing monitoring system will greatly assist an operator in proving satisfactory compliance. The device enables the provision of essential information to CASA and regulatory authorities in relation to job-safety assessments, noise regulations, insurance requirements, future airworthiness regulations, and the like. Assuming the system records data accurately, the information can be adduced to indicate compliance with regulations. Moreover, this data can be a useful data point for insurers to assist in determining fault in the event of insurance claims, and there is potential for the device to be seen as a "black box" of sorts that can provide crucial evidence of what went wrong in an incident.

Second, a drone motor bearing condition monitoring system provides an answer to strict liability offenses where the only way to avoid liability is to prevent the offense from occurring in the first place. Where these "no fault" liability regimes operate, such as in cases of Damage by Aircraft legislation or product liability under the ACL, physical prevention of the harm materializing will remain the best way to minimize legal risks. It is submitted that a bearing condition monitoring mechanism achieves just that.

Third, in the case of the common law, broadly speaking, where operators and manufacturers make efforts to build safeguards and minimize risks, the law will in some cases respond by regarding them as not at fault. The greatest use arises from fault-based torts such as negligence, where the bearing monitoring device can be supplied as evidence of reduced fault by the operator or manufacturer, showing that they have taken active steps to minimize the materialization of a known risk. For other offenses, such as trespassory torts and nuisance, though the bearing monitoring device will not reduce legal liability, it can potentially minimize the damage of an interference by reducing the velocity of landing. Otherwise, preemptively flagging before the bearing reaches a stage of catastrophic failure helps prevent exposure to liability in the first place.

A specific framework that is tailored for RPAs will enable the many economic, societal, and environmental benefits of drone innovation to be fully realized. However, until amendments are made, strict liability regimes that apply to RPAs will ensure that some legal risks remain significant. In this context, it is argued that there are both strong engineering and legal motivations to install drone bearing monitoring technology on delivery drones to mitigate some of these continuing risks.