Classifying Unmanned Aircraft Systems:
Developing a Legal Framework for the Purposes of
Airworthiness Certification

Michael John Morgan Nas
Bachelor of Laws

This thesis is presented for the degree of Master of Laws of
Murdoch University 2015
CLASSIFYING UNMANNED AIRCRAFT SYSTEMS

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

Michael John Morgan Nas
Abstract

Recent years have witnessed a paradigm shift in aviation through the evolution of unmanned aircraft technologies. However, despite the apparent potential, the integration of commercial unmanned aircraft systems (‘UAS’) into the civil aviation system has not been realised. Faced with increasing pressure from stakeholders for access to airspace, aviation regulators have adopted a cautious stance while debate about appropriate airworthiness certification takes place. Traditionally, airworthiness certification has played a central role in determining the rights and requirements for airspace use, leading to an acceptably safe system. As UAS operations may disrupt the safety balance, developing an airworthiness certification regime for UAS is critical to achieving routine airspace access.

The topic of UAS classification arises as part of the debate about certification, given the practical need to establish different requirements for different types of UAS. This thesis analyses the current approaches to UAS classification, which derive primarily from technical perspectives. The current approaches diverge in relation to the appropriate methods and objectives; specifically, there is no agreed way to design or evaluate a UAS classification scheme. It is apparent that a ‘framework of reference’ that can align objectives is vital to progress. The goal of this thesis is to propose such a framework.

Despite being noted as a complex legal question since 2004, limited legal consideration has been given to UAS classification. This thesis argues that a legal perspective explains UAS classification as an exercise in lawmaking, notwithstanding the technical aspects. Adopting this perspective, the legal techniques used to control the quality of laws can be applied towards the design and evaluation of UAS classification schemes in order to generate a ‘framework of reference’. This framework serves as a platform for more focused debate about and the convergence of the multidisciplinary knowledge necessary to progress the regulatory agenda for UAS.
# Contents

**ABSTRACT**  
3

**CLASSIFYING UNMANNED AIRCRAFT SYSTEMS: DEVELOPING A LEGAL FRAMEWORK FOR THE PURPOSES OF AIRWORTHINESS**  
10

**PREAMBLE**  
10

## I OVERVIEW  
12

## II UNMANNED AIRCRAFT TECHNOLOGY AND THE LAW  
24

### A Developments in UAS Technology  
24

1. Defining Modern UAS Technology  
26

2. Terminology and Typology  
28

3. The Market for UAS Technologies  
34

### B Developments in UAS Regulation  
37

1. Growth of Regulatory Agenda for UAS Globally  
38

2. UAS Continue to be Regulated by Exemption  
43

3. Developments towards a Comprehensive Regime for Mainstream UAS Operations  
44

## III UAS TECHNOLOGIES CONFRONT THE EXISTING SAFETY SYSTEM  
49

### A Existing System has Evolved Over Time to the Current Level of Safety  
50

### B Certification of Aircraft: A Fundamental Component of the Existing System  
53

### C Existing System is Acceptable to the Public and Flight Freedoms Granted  
57

### D Current Status of UAS Operations  
60

1. ELOS and the Precautionary Principle  
60

2. Market is Seen as Extremely Lucrative but ELOS Creates Uncertainty  
61

3. Difficulties in Controlling UAS Usage  
63
CLASSIFYING UNMANNED AIRCRAFT SYSTEMS

E Certification and Classification of UAS: Current Approaches
   1 Lack of Airworthiness Certification Basis or Pathway 65
   2 Lack of Knowledge regarding Assessment of Risk 69
   3 Lack of Ability to Assess Market Impact 73
   4 Lack of International Harmonisation 75

IV CLASSIFICATION AS A LOGICAL STARTING POINT IN CERTIFICATION

A The Nature of Classification 78
B Issues of Classification are Inherent in the Certification Challenges 81
C Difficulty in Addressing Regulation without Classification 83
D Current Approaches to Classification 84
   1 Regulatory & Standards Setting Approaches to the Classification of UAS 85
   2 Technical Approaches 97
   3 Legal Approaches 108

V ASSESSMENT OF THE CURRENT APPROACHES TO UAS CLASSIFICATION

A The Importance of Classification to UAS Certification 112
B The Core Aspects of Classification: Purposes, Methods, Structures and Key Decisions 116
   1 Purposes 117
   2 Methods 119
   3 Structures 120
   4 Key Decisions 122
C Current Approaches have not Resulted in Consensus 126
   1 Lack of Consensus as to the Purposes, Methods & Structures in Current Approaches 126
   2 Lack of Consensus as to Key Elements 128
D The Need for a framework of reference for UAS Classification 138
   1 No consensus as to the desiderata for UAS classification 139
   2 Lack of Reference Point by which to Weigh and Evaluate Desiderata 141
VI UAS CLASSIFICATION FROM A LEGAL PERSPECTIVE

A UAS Classification in Context: A Multidisciplinary Issue
B Limited Consideration of Legal Context in Current Approaches to UAS Classification
   1 Limited Substantive Consideration by Legal Sources
   2 No Detailed Analysis of Classification from a Legal Perspective
C Legal Classifications are Unique
D Applying a Legal Perspective to the Current Approaches

VII DEVELOPING A FRAMEWORK OF REFERENCE FOR UAS CLASSIFICATION

A The Regulatory System
   1 The Regulatory Regime
   2 The Regulatory Process
B Guidance for Classifying UAS Obtained from Understanding Regulatory Nature
C Classification for the Purposes of a Certification Regime
D Guidance Obtained from the Regulatory Regime
E Guidance Obtained from the Regulatory Process
   1 The Requirement to Make Rules
   2 The Requirement that Rules be Workable
   3 The Requirement to Publicise Rules or Make them Available
   4 The Requirement for Some Stability in the Rules
   5 The Requirement that Rules be Impartially Interpreted and Applied
F Applying the Legal Guidance

VIII CASE STUDY OF CLASSIFICATION FROM A LEGAL PERSPECTIVE – CASR PART 101

A CASR Part 101 Classification Scheme
B Purpose
C Method
### CLASSIFYING UNMANNED AIRCRAFT SYSTEMS

| D Structure | 189 |
| E The Key Decisions | 191 |
| 1 Criteria | 192 |
| 2 Class Boundaries | 195 |
| 3 Class Designations | 198 |
| 4 Applicable Rules | 199 |

### IX A WAY FORWARD – APPLYING A LEGAL PERSPECTIVE TO CLASSIFICATION

| A Development of an Evaluative Tool for Classification | 203 |
| B General Conclusions and Future Directions for Study | 207 |

### X SUMMARY

| 212 |

### APPENDIX 1: SELECTION OF CLASSIFICATION CRITERIA

| A Mass / MTOM / MTOW | 219 |
| B Kinetic Energy | 220 |
| C Risk Metrics | 221 |
| D Airspace Categories | 222 |
| E Other Possibilities | 222 |

### APPENDIX 2: DEFINITION OF CLASS BOUNDARIES

| A Adopting or Translating Boundaries from Manned Aviation Regulations | 224 |
| B Natural Tendency | 225 |
| C The Related Question: How Many Classes? | 226 |

### APPENDIX 3: GLOSSARY

| 228 |

### APPENDIX 4: ACRONYMS

| 231 |

### BIBLIOGRAPHY

| 233 |
# CLASSIFYING UNMANNED AIRCRAFT SYSTEMS

<table>
<thead>
<tr>
<th></th>
<th>Articles / Books / Reports</th>
<th>233</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Cases</td>
<td>241</td>
</tr>
<tr>
<td>C</td>
<td>Legislation, Regulatory Proposals and Related Materials</td>
<td>241</td>
</tr>
<tr>
<td>1</td>
<td>General Australian Legislation</td>
<td>241</td>
</tr>
<tr>
<td>2</td>
<td>Australian Aviation Legislation and Regulatory Materials</td>
<td>241</td>
</tr>
<tr>
<td>3</td>
<td>Canadian Aviation Legislation and Regulatory Materials</td>
<td>242</td>
</tr>
<tr>
<td>4</td>
<td>European Aviation Legislation and Regulatory Materials</td>
<td>242</td>
</tr>
<tr>
<td>5</td>
<td>United Kingdom Aviation Legislation and Regulatory Materials</td>
<td>243</td>
</tr>
<tr>
<td>6</td>
<td>United States Aviation Legislation and Regulatory Materials</td>
<td>243</td>
</tr>
<tr>
<td>7</td>
<td>International Regulatory Materials</td>
<td>244</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Treaties</th>
<th>244</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>Other</td>
<td>244</td>
</tr>
</tbody>
</table>

## TABLES

<table>
<thead>
<tr>
<th></th>
<th>254</th>
</tr>
</thead>
</table>

## FIGURES

<table>
<thead>
<tr>
<th></th>
<th>256</th>
</tr>
</thead>
</table>
Acknowledgements

I am grateful to Dr Reece Clothier currently of RMIT University, Melbourne, for his assistance and insights in relation to the technical aspects of UAS regulation during the earlier stages of this thesis.

I am similarly grateful to my supervisors, Professor Jürgen Bröhmer and Dr Jo Goodie for helping me to visualise and reach the later stages of this thesis.

To those of my family, friends, employers and colleagues who have endured the years in between, thank you for supplying the stable platform and the motivation I required to undertake this study.

To Janelle, my words of thanks cannot repay the patience, kindness and care you have shown me throughout, nor the support you have freely given.
Classifying Unmanned Aircraft Systems: Developing a Legal Framework for the Purposes of Airworthiness Certification

Preamble

In an article entitled ‘Golden Greats’ featured in the September 2013 issue of F1 Racing Magazine, which celebrated 50 years of the McLaren Formula 1 team, journalist Paul Fearnley considered which three F1 cars were the ‘best’ cars produced by the McLaren outfit in its history.\(^1\) It was a daunting task, as he explained:

The 60 iterations of the 39 models produced by McLaren have scored more than 180 poles and recorded more than 150 fastest laps. They have created seven champions – Fittipaldi, Hunt, Lauda, Prost, Senna, Hakkinen and Hamilton, with 12 titles between them – and won eight constructors’ titles… This means there are plenty to choose from when it comes to picking a golden anniversary top three. That, of course, makes the process more difficult, not easier… And by what parameters are they to be judged? Objective statistics provide a framework of reference, but subjectivity is what colours the final decision…\(^2\)

Many of the McLaren cars had claims to being the best, based on a variety of attributes, some of which were inherently subjective (for instance, ‘design breakthroughs’ or ‘aesthetic appeal’). Difficulties of this kind plague any assessment in which one is asked to select the ‘best’ option from a number of possibilities when there is no readily accepted means of doing so.

Strange as it might seem, these are similar difficulties to those confronting aviation regulators as they tackle the task of regulating emerging technologies such as unmanned aircraft systems (‘UAS’).\(^3\) There are so many types of aircraft that no single rule can govern them all. The quest to find more tailored regulatory solutions has created a maelstrom of possibilities, each with their own strengths and weaknesses. These solutions

---

\(^1\) Fearnley, Paul, ‘Golden Greats’ F1 Racing (Middlesex), September 2013, 48.

\(^2\) Ibid 49.

inevitably attempt to classify UAS in one way or another, perhaps based on factors such as aircraft weight, speed, airspace usage or a measure of the potential risk to the public. Yet there is no available means by which to test which approach is ‘best’.

This thesis examines that problem and suggests that a legal perspective can be used to generate a ‘framework of reference’ which, it is argued, can assist in testing and improving the quality of UAS classification schemes, so that progress can be made.

---

4 Fearnley, above n 1, 49. The phrase ‘framework of reference’ is adopted herein and used throughout this thesis. In all cases, the phrase is attributable to Fearnley.
I  OVERVIEW

As long ago as 2000, the US Department of Defense declared that half of its attack aircraft would be unmanned by 2010. By 2012 the US armed forces had amassed over 7000 UAS and while the US Air Force (‘USAF’) continues to utilise conventional attack aircraft, the F-35 Lightning is considered to be the last conventional fighter to be built for Western markets. In place of conventional aircraft, the global UAS market is projected to escalate to a value of US$89b by 2025. Indeed, by all accounts ‘the future is unmanned’ and this is a prophesy that is ‘tantalisingly close’ to reality. The prophesy is not limited to the military sphere, in fact, the latest projections indicate that military spending will decelerate over the coming years and that militaries will not continue to be the ‘bulk user’ in that market. As such, ‘drone’ manufacturers are turning to civil and commercial markets, and unmanned aircraft are already entering civil airspace around the world.

5 See, eg, Otto Kreisher, ‘The Right Number’ (2006) 49(7) Sea Power 16. The term ‘unmanned’ is used because that is the accepted usage internationally, despite that it is not a gender neutral expression: See, eg, International Civil Aviation Organization, ‘Unmanned Aircraft Systems (UAS)’ (Circular, 328/AN190, 2011) (‘Circular 328’). This is a legal issue to be resolved in the course of developing regulations for UAS: See generally Mark Peterson, ‘The UAV and the Current and Future Regulatory Construct for Integration into the National Airspace System’ (2006) 21 Journal of Air Law and Commerce 521, n 38.
12 UAS Vision, above n 9.
The numbers of civil UAS in development are on the rise. Manufacturers and operators want their UAS to have access to the civil airspace in order to conduct operations. These operations are as vast and varied as the relevant technologies, which ‘come in all shapes and sizes’, from the miniscule to the gigantic – the variation being ‘limited only by imagination’. Compare for instance the Lockheed Martin Desert Hawk and the Northrop Grumman Global Hawk. The two Hawks could not differ more – the fuselage of the former weighs under 4kg and is made of a lightweight foam, launched by hand and considered to be disposable if necessary. The latter Hawk has a wingspan longer than a Boeing 737, is capable of flights upwards of 48 hours in duration, and has a unit cost in the tens of millions. Both technologies have been in service since the mid-2000s, and variously modified and upgraded over time. With respect to newer technologies, the ‘aircraft’ at the lower end of the weight scale could fit in the palm of one’s hand, and their weight would be measured in grams. Given the expectation that within the coming decade unmanned aircraft will be ‘incomprehensibly small by today’s standards’, it is clear that it will not be long before even cutting edge thinking towards UAS will soon be outmoded.

All of these craft may be ‘coming to the sky near you’. While current commercial uses are largely restricted and generally confined to operations away from the populated areas where they could be the most useful, in the US, General Atomics Predator B drones have

---

13 See generally Hayhurst et al, Unmanned Aircraft Hazards, above n 11, 1.
15 Ibid 588.
20 Ibid.
been on near-constant patrol of the US-Mexican border since 2005, utilising a specially created flight corridor.\textsuperscript{23} That same year the National Aeronautics and Space Agency (‘NASA’) began using a Predator B variant called \textit{Ikhana} to conduct scientific missions over the US, including wildfire imaging missions from 2007 to 2009 flown out of California.\textsuperscript{24} These are similar to the models of UAS used by the USAF in Afghanistan and Iraq. Elsewhere, UAS have been used to monitor volcano activity since about 2004.\textsuperscript{25} Startlingly, Japan has been using a fleet of hundreds of privately operated unmanned helicopters for agricultural spraying since 1988.\textsuperscript{26} In Europe, an unmanned aircraft transitioned public airspace under the watchful eye of the UK Civil Aviation Authority (‘CAA’) in April 2013 – the first official flight of its kind.\textsuperscript{27} Tech giants Amazon and Google want to use drones to deliver goods to your door.\textsuperscript{28} An Australian company proposes to deliver text books.\textsuperscript{29}

In fact, Australia was amongst the first in the world to publish regulations for UAS in 2002,\textsuperscript{30} and parliament has renewed its commitment to UAS regulation in its sweeping

\textsuperscript{24} Ibid 636.
\textsuperscript{25} Ibid.
\textsuperscript{26} Hanlon, Mike, \textit{Yamaha’s RMAX - the world’s most advanced non-military UAV} (4 June 2014) \langle http://www.gizmag.com/go/2440\rangle.; Laurence Newcome, \textit{Unmanned Aviation: A Brief History of Unmanned Aerial Vehicles} (American Institute of Aeronautics and Astronautics, 2004), 127; Cf Hayhurst et al, \textit{Unmanned Aircraft Hazards}, above n 11, 2, which states that UAS have been used in Japan for these purposes since 1991.
\textsuperscript{27} Sofia Michaelides-Mateou and Chrystel Erotokritou ‘Flying into the Future with UAVs: The Jetstream 31 Flight’ (2014) \textit{39 Air & Space Law} 111, 111 (albeit that it carried crew on board to conduct take-off and landing).
\textsuperscript{29} See Michaelides-Mateou and Erotokritou, above n 27, 114; See also Nassim Kadem, ‘Textbook delivery: Zookal delivers students’ books using flying drones’ (15 October 2013) \textit{Australian Financial Review} \langle http://www.afr.com/it-pro/textbook-delivery/zookal-delivers-students-books-using-flying-drones-20131126-jz8ze\rangle.
\textsuperscript{30} Australia amended the \textit{Civil Aviation Safety Regulations 1998 (Cth)} (‘CASRs’) to incorporate regulation relating to UAS in 2002: Civil Aviation Safety Authority (Australia), \textit{CASR Part 101 – Unmanned aircraft and rockets} \langle https://www.casa.gov.au/standard-page/casr-part-101-unmanned-aircraft-and-rocket-operations\rangle. The approach of the Civil Aviation Safety Authority (‘CASA’) has been described by some as the ‘envy of the world’: See Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1005.
Aviation White Paper policy statement released in 2013 (‘Aviation White Paper’).31 Australia also has a successful and long-standing history in developing unmanned aircraft – the Government Aircraft Factory having designed and produced the remarkable, 1300kg turbojet-powered Jindivik target drone for export for 40 years from about 1948.32 In 1995 the Australian-made Aerosonde UAS was used over Western Australian coastal waters to monitor cyclone formation,33 blazing a trail for civil operations globally. Leveraging this experience, Australia is now well positioned from a technical and legal standpoint to capitalise on the rapid growth of the civil market for UAS technologies. Similar sentiments are apparent in Europe and the US; both of which have stated expectations that the skies will be opened to UAS within the next year,34 US congress actually mandating that full integration occur by 30 September 2015.35 This gives rise to some very difficult problems in regulation.36

These problems stem from one key change: removing the pilot from the cockpit. It is a simple idea, in some ways, but it is one that has unleashed the creative talents of an industry and provoked new ways of thinking in aviation. The sky is quite literally the limit – and even then some proposals involve building unmanned aircraft that can operate both within and beyond the atmosphere.37 As such, the simple idea to relocate or remove the

---

33 See Walker, Malcolm M J M, ‘The Evolution of Specific Legislation Governing Australian Unmanned Aerial Vehicles (UAVs)’ (Discussion Paper, Civil Aviation Safety Authority - Australia, 9 June 1999) (‘Evolution’). Note that this paper is not generally available, but can be obtained from the library section of www.rpas-regulations.com (<http://rpas-regulations.com/index.php/library/rules-and-standards#Australia>) though membership to the site is required.
35 FAA Modernization and Reform Act of 2012, Pub L No 112-95, § 331(a)(3), Pub L No 112-95. Note however that this is a formidable task which has not been met by the FAA at the time of writing.
pilot has left aviation regulators facing a complex problem: how to regulate UAS so as to ensure the safety of airspace users and the public generally when UAS are so ‘fundamentally different’ than conventional aircraft in relevant and critical ways.

A particular issue in regulation that has been identified by those studying the topic is the way in which UAS ought to be certified as safe for operation. Given the many differences between UAS and conventional aircraft, UAS cannot simply comply with the existing airworthiness certification regime that has developed over time as conventional aviation has developed. Further still, the extreme diversity prohibits a broad brush approach to UAS. As such, numerous sources have identified the need to develop – as a first step – a classification scheme for UAS that can account for the extraordinary diversity of UAS so that certification requirements for each class can be established, in a similar fashion to the type certification regime in place for conventional aircraft. Classification, as a concept for study, is more often directly encountered by that name in the natural sciences and

---

38 This thesis refers to the aviation safety regulators in Australia, Canada, Europe, the UK and the US as the ‘regulators’; that is, CASA, Transport Canada (‘TC’), the European Aviation Safety Agency (‘EASA’), the Civil Aviation Authority (‘CAA’), and Federal Aviation Administration (‘FAA’), respectively.

39 Hayhurst et al, above n 11, 3.


41 See generally Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1004.

engineering than in law;\textsuperscript{43} thus the topic has largely been tackled from technical perspectives to date.\textsuperscript{44} But classification also plays an important part in the study and creation of law, as described by the former US Chief Justice Taft (also former President of the US) in 1921:

Classification is the most inveterate of our reasoning processes. We can scarcely think or speak without consciously or unconsciously exercising it. It must therefore obtain in and determine legislation; but it must regard real resemblances and real differences between things, and persons, and class them in accordance with their pertinence to the purpose at hand.\textsuperscript{45}

The utility of classification as a reasoning device is that it can be used to distil the potentially large number of observable differences between things to a smaller, more manageable number of specific differences so that groups of things sharing certain characteristics (rather than individual things) can be dealt with in some way. The challenge for classifying UAS, from a legal perspective, is to identify the relevant purposes driving the classification, and thereby to ensure that real and relevant similarities and differences are used as a basis for establishing classes of UAS. By that means, appropriate certification requirements can be crafted for each class of similar UAS.\textsuperscript{46}

In the course of the following 8 Chapters, this thesis explores the issue and specifically identifies the critical role that classification plays in the development of regulations for UAS. This thesis has several, sequential objectives:


\textsuperscript{45} \textit{Truax v Corrigan}, 257 US 312, (Ariz, 1921), 337-338 (Per Taft CJ). Of course, these are considerable aims that may be difficult to achieve in practice, and the \textit{Truax} case itself is an example of the difficulties involved as well as the influence of social context in classification. While adopting the sentiments extracted above, this thesis does not otherwise comment on the case or the views expressed in it.

\textsuperscript{46} See Milan Plucken, \textit{The Regulatory Approach of ICAO, the United States and Canada to Civil Unmanned Aircraft Systems in Particular to Certification and Licensing} (Masters Thesis, McGill University, 2011), 95; Stefan A Kaiser, ‘UAVs and Their Integration into Non-Segregated Airspace’ (2011) 36(2) \textit{Air and Space Law} 161 (‘UAVs and Their Integration’); See also AAIF \textit{Report}, above n 11.
(a) to describe the background to the issue of classification in terms of the current state of UAS technology, and the current status of the laws intended to regulate the technology;

(b) to outline the ways that UAS technologies confront rather than conform to the existing safety system, particularly the existing airworthiness certification regime for UAS;

(c) to explain the classification of UAS as a particular issue – and a logical starting point – in the certification of UAS, and to present the current regulatory, technical and legal approaches to the classification of UAS to date;

(d) to assess the current approaches to classification in terms of their core aspects and to identify the lack of consensus that is apparent for each aspect. In light of the lack of consensus, a corollary objective is to identify the need for a framework against which the quality of a classification scheme can be measured;

(e) to observe the limited legal consideration so far given to classification and to propose a means by which UAS classification, as a legal classification, can be assessed;

(f) having identified the need for a framework to evaluate the quality of a classification scheme, to develop such a framework by drawing on legal principles and to argue that this can assist in overcoming the difficulties encountered in classifying UAS;

(g) to demonstrate the utility of a legally-derived framework by utilising it in a case study evaluation of existing UAS regulation; and

(h) to reflect on the case study in order to propose adjustments and further work in the area that can refine the proposed framework.

It is necessary to set out these arguments in a linear fashion that follows the structure of this thesis. Chapter II of this thesis examines the interface between UAS technology and the law. Remote control concepts have existed in aviation for a considerable time, with the concepts varying in complexity, configuration and application over the years. This creates difficulties in defining what is meant by the phrase ‘unmanned aircraft’, leading to an array of terminologies and typologies to suit the increasing diversity. That same diversity has led to significant growth in the UAS market, with that growth predicted to continue. In the face of growing demand for UAS services and increasing availability of the technology, regulators must ensure that existing safety standards are maintained without
unduly penalising the fledgling UAS industry.\textsuperscript{47} Chapter II concludes by introducing these significant regulatory issues as background to the specific issue of classification, which is inevitably bound up with these background issues.

Chapter III develops the point further: UAS present a difficult fit with the existing legal structures that have evolved over the course of 100 years of conventional aviation, and are seemingly incompatible with the existing system.\textsuperscript{48} With limited knowledge of the risks,\textsuperscript{49} and acting to preserve public safety, aviation regulators have adopted a ‘precautionary approach’ such that UAS operations are prevented or restricted until an Equivalent Level of Safety (‘ELOS’) has been proven. That is, UAS must ‘first do no harm’.\textsuperscript{50} This approach has an obvious and negative effect on the viability of UAS operations in the short term. Apart from being ambiguous as an objective, it provides no guidance as to how to reach a satisfactory level of safety.\textsuperscript{51} Chapter III outlines a particular issue in regulation relating to the airworthiness certification of UAS. For conventional aircraft, airworthiness


\textsuperscript{48} Hayhurst et al, \textit{Unmanned Aircraft Hazards}, above n 11, 1, 11; Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 872.

\textsuperscript{49} In this thesis I refer to risk only in the sense of a ‘safety risk’, consistent with Jeffrey Maddalon, Kelly J Hayhurst, A Terry Morris and Harry A Verstynen, ‘Considerations of Unmanned Aircraft Certification for Civil Airworthiness Standards’ (Paper presented at American Institute of Aeronautics and Astronautics Infotech Conference, Boston Massachusetts, August 19-22, 2013) 2 <http://shemesh.larc.nasa.gov/people/jmm/Infotech_2013_v8j.pdf> (‘Considerations of Unmanned Aircraft’). Specifically risk is considered in terms of potential damage to persons or property on the ground, being (arguably) the primary risk for UAS in relation to airworthiness certification: See eg Reece A Clothier, Jennifer L Palmer, Rodney A Walker and Neale L Fulton, ‘Definition of an Airworthiness Certification Framework for Civil Unmanned Aircraft Systems’ (2011) 49 \textit{Safety Science} 871, 874 (‘Airworthiness Certification Framework’); Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 2; Clothier and Walker, \textit{Casualty Risk Analysis}, above n 40, 3; Whilst it may be that UAS certification must take account of operational aspects of airworthiness (see Kaiser, ‘UAVs and Their Integration’ above n 46, 170-171), consideration of mid-air collision factors (arguably an ‘operational’ issue separate from ‘technical airworthiness’ per the AAIF Report, above n 11, 7) is beyond the scope of this thesis. Similarly, consideration of broader societal risk is beyond the scope of this thesis. For general discussion of risk, see Clothier et al, ALARP and Risk Management, above n 44 3-13; Clothier and Walker, \textit{Determination and Evaluation of Safety Objectives}, above n 47, [1.1].


\textsuperscript{51} See generally Clothier and Walker, \textit{Determination and Evaluation of Safety Objectives}, above n 47, 1.
certification provides the relevant safety assurances and, as such, the certification of UAS is a key piece of the puzzle in understanding and meeting the ELOS requirement. However, given that existing procedures are largely inapplicable to UAS, the way forward is unclear.

The question of classifying UAS is closely allied with the certification issue. Chapter IV therefore analyses the concept of classification in greater detail, commencing by observing that issues of classification are evident in several challenges relating to UAS certification, and that classification therefore represents a ‘foundational’ part of the solution. Chapter IV then sets out an overview of the various approaches taken to classification that are evident in proposals for UAS regulation put forward by safety regulators in Australia, Canada, Europe, the UK and the US. Numerous important studies conducted by safety scientists, engineers and academics are also reviewed. Finally, a review of the legal consideration dealing specifically with UAS classification is presented in concluding the Chapter.

An assessment of the approaches overviewed in Chapter IV is conducted in Chapter V. The importance of classification has been confirmed by numerous regulatory, industry and academic sources, including recent guidance studies by the National Aeronautics and Space Administration (‘NASA’) and the International Civil Aviation Organisation (‘ICAO’), both of which concluded that the topic is a work in progress. Despite the trend toward more rigorous, statistically-based methods said to more closely correlate with regulatory objectives, there remains no consensus as to the core aspects of classification for UAS in terms of the purposes, methods and structures used in the classification exercise. The same is true of the 4 key decisions or ‘preferments’ that need to be made in relation to classification: determining the relevant characteristics or criteria by which

52 See Takahashi, above n 21, 522, 533; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 5.
differences between UAS are to be assessed; specifying the boundaries or groups according to the characteristics; designating the names given to these different groups, and developing the rules that apply to each group. The upshot is, in my assessment, that the current approaches exhibit the need for the production of a *framework of reference*; that is, there is a need for a clear set of reference points which can guide discussion with a view to achieving effective classification (and hence effective regulation).

It is significant that although it has been recognised since 2004 that classification presents a complex legal issue, many studies have approached the classification exercise from a legal perspective – most studies are derived from risk management, engineering or statistical/mathematical perspectives as discussed in Chapter IV. The idea that UAS classification can be studied from a legal perspective is taken up in Chapter VI. This thesis argues that UAS classification has an important - but often marginalised - legal character because a classification of UAS will form part of a certification regime which exists as delegated or secondary legislation. Chapter VI explains that legal or ‘official’ classifications are unique and distinct from other kinds of classification (for instance, scientific classification) due to the rights and obligations that attach to the classification exercise. The Chapter concludes that the creation of a classification scheme can be viewed as part of the broader creation of airworthiness regulations for UAS, and in that regard the task is a lawmaking task when properly considered in its context.

Chapter VII proceeds to develop a framework of reference for UAS classification. As a starting point it is important to locate the classification task within the broader ‘regulatory system’, which is comprised of substantive laws (primary and subsidiary legislation) known as the ‘regulatory regime’, as well as ‘meta-rules’ that define how the substantive laws are made (known as ‘regulatory process’). Specifically, UAS classification (as a task in certification) is an issue for secondary legislation. By accepting that UAS classification must therefore achieve the substantive objectives of the regulatory regime

---

56 DeGarmo, above n 42, [2-41].
57 See Starr, above n 55, 263.
and comply with the meta-rules of the regulatory regime in terms of how these classifications are to be created, critical guidance can be obtained. Importantly, I argue that the adoption of a legal perspective in this way can provide a set of stable and authoritative principles upon which to evaluate the quality of a classification scheme, and thereby provide the critical framework of reference that is needed to progress regulation.

Chapter VIII brings together the understanding of UAS classification that emerges from Chapters VI and VII as a basis for analysing UAS classification from a legal perspective. That is, Chapter VIII illustrates that this legal perspective can inform and generate a useful framework of reference which has not emerged amongst the current approaches to date. Specifically, Chapter VIII draws on the important guidance that can be elucidated by examining the classification task in the context of the regulatory system, as well as using a simplified understanding of classification in terms of the core aspects which comprise the classification task. Chapter VIII utilises the existing UAS regulations in Part 101 of the Civil Aviation Safety Regulations 1998 (Cth) (‘CASR Part 101’) as a case study with a view to validating the proposed framework of reference.

The final Chapter reflects on the application of the legal perspective in the case study carried out in Chapter VIII. Chapter IX forms general conclusions as to the utility of the legal perspective in developing a practical tool for the design and evaluation of a classification scheme. A primary contribution of this thesis is that in describing a framework of reference, a legal perspective can provide a sound platform for arranging and framing debate amongst the technical sources and guiding future work towards the creation of appropriate regulation. The limitations to the legal perspective are acknowledged, and the need for a multidisciplinary approach to the problem is emphasised. That is, while the legal perspective can provide a useful, general structure that can frame debate it is unlikely that a legal perspective alone can resolve the issue of classification. Rather, this is likely to arise only through the combined efforts of legal, technical and economic input.

In terms of scope, this thesis is limited in scope to consideration of the need to identify an appropriate certification regime by which to determine safety standards specifically for
commercial UAS (being those for hire or reward).\textsuperscript{59} The volume of literature available globally in relation to that issue prohibits a comprehensive consideration of all relevant work. Therefore, the sources referred to in this thesis are considered to be seminal or significant (historically or in terms of ongoing developments) and, while Australian laws and regulations are central to consideration, efforts have been made to ensure that the considerations and conclusions herein are broadly applicable. Finally, the rapid pace of change within the UAS regulatory domain under study means that an end date for the materials reviewed must be defined. This thesis is current to approximately March 2015.

\textsuperscript{59} Consideration of issues relating to pilot certification and airspace management issues may be considered to be separate issues and are beyond the scope of this thesis: See Joint Aviation Authority/Eurocontrol Initiative on UAVs, ‘UAV Task-Force Final Report: A Concept for European Regulations for Civil Unmanned Aerial Vehicles (UAVs)’ (Working Group Final Report, JAA/Eurocontrol, 11 May 2004), 16 (‘JAA/Eurocontrol Report’). However, as noted above there may be a degree of overlap for UAS between airworthiness certification, pilot certification and airspace management: See, eg, AAIF Report, above n 11, 7. This thesis focuses solely on the issue of aircraft certification as a primary issue in regulating UAS. Furthermore, this thesis is concerned only with commercial UAS (being those operated by private entities, essentially for commercial gain or commercial purposes), and not those operated by a State, which may be subject to separate legal treatment internationally: See Elmar M Giemulla, ‘Chicago System: Genesis and Main Characteristics’ in Elmar M Giemulla and Ludwig Weber (eds), \textit{International and EU Aviation Law: Selected Issues} (Kluwer Law International, 2011) 3, 51-54 (‘Chicago System’). The term ‘State’ is used generally herein to denote a Contracting State to the \textit{Chicago Convention}.\textsuperscript{7}
II UNMANNED AIRCRAFT TECHNOLOGY AND THE LAW

A Developments in UAS Technology

It is not the place of this thesis to provide a comprehensive summary of the history of unmanned aircraft – that is a history that has been studied in great detail in recent years and which is replete with curiosities and achievements tracing back at least as far as the 19th Century. Early drones were designed and used as prototypes, testbeds and model aircraft at least from 1848, though the rudimentary nature of the technology does not reconcile easily with the modern definitions of ‘unmanned aircraft’, unmanned aerial vehicle (‘UAV’) or UAS. Various attempts have been made to adequately define the nature of unmanned aircraft over time, but consensus is made difficult by the fact that modern UAS technologies resemble conventional aircraft on the one hand and yet, on the other hand, may also be so alien to conventional concepts that it is difficult to regard UAS as aircraft at all. In that regard, compare the Global Hawk and the Desert Hawk UAS mentioned above.

The question as to whether UAS are or aren’t ‘aircraft’ is more than a semantic issue – real issues arise as to how UAS fit within an existing and acceptably safe aviation system, as well as the degree of regulatory treatment that ought to be applied to ensure the continuing safety of that system. One of the key components in the regulatory oversight of conventional aircraft operations is the certification issued by regulators that a particular aircraft is airworthy. By this process, the design, manufacture and performance of an aircraft is controlled in such a way that the regulator (and the public) are assured of safety of an aircraft in terms of its fitness to fly. Given each ‘type’ of aircraft presents unique safety implications depending on its design, manufacture and performance, the existing

---


62 See Chapter III.B below; See also Takahashi, above n 21, 520-523.

63 Takahashi, above n 21, 520-523.
safety system therefore operates by reference to different types, classes and categories of aircraft, with different standards (and different rights and obligations) applicable to each.\textsuperscript{64} The issues of type and treatment are therefore historically linked when it comes to regulating conventional aircraft. In this Chapter I wish to expand on these issues in so far as they lead to the present challenges in classifying UAS.

The challenges lie in the fact that the fact that the breadth and pace of the development of UAS over time casts significant doubt as to the appropriate types and the appropriate treatment. Historically, the development of UAS has witnessed the transition of UAS technology from basic civilian prototypes and model aircraft, to military machines used as expendable target aircraft and sacrificial ‘flying bombs’, to the present military and civilian applications in reconnaissance and surveillance undertaken by sophisticated and partly autonomous technologies.\textsuperscript{65} For the last decade, the development of UAS for civil and commercial use has proliferated; this is apparent in the global market data:\textsuperscript{66}

<table>
<thead>
<tr>
<th>Year</th>
<th>Total UAS</th>
<th>No. Developers</th>
<th>No. Civil UAS</th>
<th>% Civil UAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>544</td>
<td>207</td>
<td>55</td>
<td>10.11</td>
</tr>
<tr>
<td>2006</td>
<td>603</td>
<td>252</td>
<td>47</td>
<td>7.79</td>
</tr>
<tr>
<td>2007</td>
<td>789</td>
<td>312</td>
<td>61</td>
<td>7.73</td>
</tr>
<tr>
<td>2008</td>
<td>974</td>
<td>369</td>
<td>115</td>
<td>11.81</td>
</tr>
<tr>
<td>2009</td>
<td>1190</td>
<td>422</td>
<td>150</td>
<td>12.61</td>
</tr>
<tr>
<td>2010</td>
<td>1244</td>
<td>500</td>
<td>171</td>
<td>13.75</td>
</tr>
<tr>
<td>2011</td>
<td>1424</td>
<td>511</td>
<td>174</td>
<td>12.29</td>
</tr>
<tr>
<td>2012</td>
<td>1581</td>
<td>478</td>
<td>217</td>
<td>13.73</td>
</tr>
<tr>
<td>2013</td>
<td>1708</td>
<td>510</td>
<td>247</td>
<td>14.46</td>
</tr>
</tbody>
</table>

\textsuperscript{64} Fillipo De Florio, \textit{Airworthiness: An Introduction to Aircraft Certification – A Guide to Understanding JAA, EASA and FAA Standards} (Butterworth-Heinemann, 2006), [4.6.3].

\textsuperscript{65} See the history of UAS development recounted in the sources listed in above n 60. The term ‘flying bomb’ is used in various sources; see for instance, Sullivan, above n 60, \textit{The Rise of UAVs – IEEE}, 44.

\textsuperscript{66} Compiled from the ‘Reference Tables’ contained in UVS International (formerly EuroUVS) Yearbooks entitled ‘The Global Perspective’, 2005 to 2015 (available at http://www.uvs-info.com). Each of the Yearbooks used in compiling the above data is separately set out in the bibliography to this thesis. For the purposes of the above table, ‘Civil UAS’ are considered to be those described as ‘Civil/Commercial’ in the reference tables contained in each yearbook.
It appears that while the total number of UAS in development or production has nearly quadrupled since 2005 globally, the number of civil/commercial UAS has increased nearly ten-fold. There is also a notable spike in civil UAS development in the last year. Hence, this thesis is focused on developments in the regulation of the commercial sector.

1 Defining Modern UAS Technology

In 1999, the predecessor to UVS International noted the staggering pace of development in the UAS sector and, in light of the variety of different types available, posed the question as to ‘what, precisely, a UAV is?’ Conventional aircraft have traditionally been described in terms of their size, weight, power unit, wing configuration, passengers carried or operation type. Through combinations of these descriptors, recognisable ‘types’ of aircraft emerge: for instance, a fixed-wing Boeing airliner and a Bell Helicopter are clearly distinct types but nonetheless both are identifiable as aircraft. The situation is more complicated for UAS. The defining feature for UAS is that there is no human pilot on-board an unmanned aircraft, and as such the variations in the traditional characteristics are nearly endless. Furthermore, unlike conventional aircraft, a reasonable amount of system componentry used to achieve and maintain flight (such as the operator control interface) are not on-board the aircraft.

---

69 Weibel and Hansman, above n 47, 36.
According to UVS International’s catalogue of the current fleet of UAS, the heaviest unmanned aircraft is that of the Northrop Grumman X-47B UCAS-D, an Unmanned Combat Aircraft System (‘UCAS’) in development with a planned MTOW of over 2000kg – that is roughly the weight of a Gulfstream jet, or a bus. The heaviest civil machine is the EuroHawk – a modified Global Hawk weighing 14,630kg. At the other end of the scale, the lightest unmanned aircraft recorded weighs only 0.08kg – about the same as an AA battery, or a small bird. In fact, that the US Defense Advanced Research Projects Agency (‘DARPA’) Nano Air Vehicle of that weight is designed to mimic the movements of a hummingbird. The wing designs of unmanned aircraft also differ greatly across the fleet; aside from more conventional fixed-wing and rotary-wing, many other configurations are possible given the lack of pilot on board the craft, such as tilt-rotor, tilt-wing, and tilt-body. There are also significant variations in power units (electric motors, piston or jet engines) as well as control schemes, which can vary enormously - from the use of a ‘ground station’ with a virtual cockpit replicating a traditional cockpit, to navigation via programmed GPS waypoints, to the use of handheld equipment very similar to RC/model airplanes. More recent innovations involve ‘piloting’ the UAS via an iPad.

---

70 In terms of Maximum Take-Off Weight (‘MTOW’), sometimes referred to as Maximum Take-Off Mass (‘MTOM’). This thesis uses the term MTOW, mass and weight interchangeably, in a manner consistent with Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 6 n 4.
72 Ibid 175.
74 Schoen, above n 19, 18; See Yearbook 2015, above n 71, 199.
75 Wikipedia, AeroVironment Nano Hummingbird, above n 73.
The diversity of unmanned aircraft is far greater than the range apparent amongst conventional aircraft, presumably because the ‘limiting factor’ – the human pilot – no longer has any direct effect on the size or configuration of the aircraft. Unmanned aircraft can therefore be designed purely to achieve their commercial or civil applications. To that end, UAS design is driven by the intended application to a far greater extent than is evident in the design of conventional aircraft. The fact that these potential applications are essentially ‘limitless’ has led to an explosion of diversity amongst UAS. According to CASA, more than 650 possible civil applications have been identified for UAS. The question as to what a UAS is therefore remains unsettled.

2 Terminology and Typology

This diversity in UAS design and application reflects in the terminology and typology applicable to UAS. For instance, in describing and analysing its database of UAS information, UVS International employed the following labels in its 2015 Yearbook:

<table>
<thead>
<tr>
<th>Category Descriptors</th>
<th>Class Descriptors</th>
<th>Airframe Descriptors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nano</td>
<td>Civil/Commercial</td>
<td>Fixed Wing</td>
</tr>
<tr>
<td>Micro</td>
<td>Dual Purpose –</td>
<td>Flapping Wing</td>
</tr>
<tr>
<td>Mini</td>
<td>Civil/Military</td>
<td>Parafoil</td>
</tr>
<tr>
<td>Close Range (CR)</td>
<td>Developmental Aircraft</td>
<td>Rotary Wing</td>
</tr>
<tr>
<td>Short Range (SR)</td>
<td>Electronic Warfare</td>
<td></td>
</tr>
</tbody>
</table>

---

80 See for instance Palmer and Clothier, above n 36, 233.
82 McBride, above n 23, 629.
83 That is, the characteristics of the airframe will be influenced almost exclusively by intended application. Kaiser notes for instance that the weight of a UAS will be influenced by payload predominately: Stefan A Kaiser, ‘Legal Aspects of Unmanned Aerial Vehicles’ (2006) 55(3) Zeitschrift für Luft- und Weltraumrecht 344, 345 (‘Legal Aspects of UAVs’).
84 See generally Palmer and Clothier, above n 36, 233.
85 AAI Report, above n 11, 2; Michaelides-Mateou and Erotokritou, above n 27, 113.
86 McBride, above n 23, 629; Some have attempted to study and quantify the nature and extent of the diversity – these studies are examined in further detail in this thesis in so far as they relate to the classification of UAS.
88 See eg Yearbook 2015, above n 71, 163.
This array of terminology is used to describe an assortment of somewhat exotic technologies all congregating under the one banner. Given the diversity, there is a question as to formulating an appropriate definition of UAS for regulatory purposes, and a further question as to the relevant types of UAS for the purposes of regulatory treatment.

Unmanned aircraft have been adorned with various names over the years and the names have been adjusted from time to time to take account of changes in technology, as well as the social, political and regulatory reactions to those changes. At least the following names have been used: ‘drones’, 89 ‘pilotless aircraft’, 90 ‘remotely piloted vehicles’ (‘RPVs’), ‘remotely piloted aircraft’ (‘RPA’), ‘remotely operated aircraft’ (‘ROA’), 91 and more recently ‘unmanned aerial vehicle’ (‘UAV’) and ‘unmanned aircraft system’ (‘UAS’). 92 or

---

90 Convention on International Civil Aviation signed 7 December 1944, 15 UNTS 296 (entered into force 4 April 1947) art 8 (‘Chicago Convention’).
sometimes ‘uninhabited aircraft system’ (also ‘UAS’). The shifting names given to UAS technologies place points of emphasis on different issues. For example, the distinction between a ‘pilot’ in ‘RPA’ and ‘operator’ in ‘ROA’ speaks to the control scheme used in the technologies in question; the debate as to whether unmanned aircraft are ‘aircraft’ or some other kind of ‘aerial vehicle’ can also be observed in the difference between the usage of ‘UAV’ and ‘UAS’. Importantly, the movement towards the use of the term ‘UAS’ signifies a growing recognition that the aircraft component of the system is but one part of a broader operational system that involves ground systems and communication links etc.

Although these terms are commonly used ‘interchangeably’, the definitional problems create issues at a regulatory level. This is because regulatory authority is dependent upon whether UAS technologies fall within the ambit of regulatory purview defined by the Convention on Civil Aviation 1944 (‘Chicago Convention’), upon which the modern safety system is based. For many years, UAS were considered to be ‘aerial vehicles’ or ‘non-aircraft’, placing UAS in a similar category to model aircraft or other exempted operations and raising questions as to the place of UAS in the regulatory scheme. Some have noted that the word ‘aircraft’ as used (but not defined) in the Chicago Convention...
‘does not exclude’ unmanned aircraft, and others note that traditional definitions of ‘aircraft’ make no reference to the need for ‘wings or a pilot’. On the other hand, art 8 of the Chicago Convention stipulates that a different (perhaps, cautious) approach is specifically to be taken to ‘pilotless aircraft’, which suggests that UAS are a different species of technology. This gives rise to a number of issues dealt with in further detail in Chapter III.

However, whatever the historical position, the debate as to the place of UAS within the aviation safety system has recently been settled by the peak international body – the ICAO – which has issued guidance clarifying that UAS are ‘aircraft’ for the purposes of safety regulation. In its guidance, ICAO in fact coined further terminology - ‘Remotely Piloted Aircraft System’ (‘RPAS’). The phrase was used quite intentionally by the ICAO, as it refers to a specific kind of control scheme used in operation in the UAS-AC, leaving other kinds of UAS aside for further guidance in due course.

While the term UAV is essentially being phased out by the regulators, the term UAS will endure for now as it capture all types of unmanned aircraft, with RPAS being but one subset. Though regulators have experienced difficulties in defining UAS for legal purposes, this ‘systems’ approach has recently been recognised in executive level reporting by the FAA, describing UAS as being ‘entire system[s] [of] of aircraft, data links, control station and other elements’ which range from ‘remotely piloted vehicles with limited capabilities to semi and fully autonomous systems’. For these reasons I will

100 Maneschijn et al, above n 42, 346; See generally Anna Masutti, ‘Proposals for the Regulation of Unmanned Air Vehicle Use in Common Airspace’ (2009) 34(1) Air & Space Law 1, 3; Plucken, above n 46, 38.
101 Takahashi, above n 21, 500.
102 See Chicago Convention art 8, the text of which is extracted in Chapter III. See generally Kaiser, ‘Legal Aspects of UAVs’, above n 83, 348.
103 Circular 328, above n 5, 2 at [1.6].
105 B C Kessner, ‘UAV Sense-and-Avoid Technologies Not Just a Military Concern’ (2005) 227(22) Defense Daily 1, [6], the use of the term if ‘going away’ per the FAA.
106 See ICAO’s submission to UVS International, ‘Yearbook 2011’, above n 104, 112; Plucken, above n 46, 22
refer herein to UAS.\textsuperscript{108} When referring to the aircraft component of the UAS, this thesis generally uses the term Unmanned Aircraft System – Air Component (‘UAS-AC’).\textsuperscript{109}

Beyond that broader definitional issue, there are difficulties in pinpointing the accepted names for different types of UAS and the accepted meaning of the terminology used in the UAS sector. That is, there is no agreed typology for UAS; rather, the UAS market is awash with numerous names for UAS, apparently intended to describe their attributes and capabilities. Nonetheless, understanding the different types of UAS is important in determining the level of regulatory treatment to be applied, as different types require different treatment.\textsuperscript{110} The UAS classification developed by UVS International provides an important insight into the general understanding amongst the UAS industry itself as to the classes of UAS and their characteristics:\textsuperscript{111}

<table>
<thead>
<tr>
<th>RPAS Categories</th>
<th>Acronym</th>
<th>Range (KM)</th>
<th>Flight Altitude (m)</th>
<th>Endurance (hours)</th>
<th>MTOW (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tactical</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nano</td>
<td>η</td>
<td>&lt; 1</td>
<td>100</td>
<td>&lt; 1</td>
<td>&lt; 0.025</td>
</tr>
<tr>
<td>Micro</td>
<td>μ</td>
<td>&lt; 10</td>
<td>250</td>
<td>1</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Mini</td>
<td>Mini</td>
<td>&lt; 10</td>
<td>150 to 300</td>
<td>&lt; 2</td>
<td>&lt; 30 (150)</td>
</tr>
<tr>
<td>Close Range</td>
<td>CR</td>
<td>10 to 30</td>
<td>3000</td>
<td>2 to 4</td>
<td>150</td>
</tr>
<tr>
<td>Short Range</td>
<td>SR</td>
<td>30 to 70</td>
<td>3000</td>
<td>3 to 6</td>
<td>200</td>
</tr>
<tr>
<td>Medium Range</td>
<td>MR</td>
<td>70 to 200</td>
<td>5000</td>
<td>6 to 10</td>
<td>1250</td>
</tr>
<tr>
<td>Medium Range Endurance</td>
<td>MRE</td>
<td>&gt; 500</td>
<td>8000</td>
<td>10 to 18</td>
<td>1250</td>
</tr>
<tr>
<td>Low Altitude Deep Penetration</td>
<td>LADP</td>
<td>&gt; 250</td>
<td>50 to 9000</td>
<td>0.5 to 1</td>
<td>350</td>
</tr>
<tr>
<td>Low Altitude Long Endurance</td>
<td>LALE</td>
<td>&gt; 500</td>
<td>3000</td>
<td>&gt; 24</td>
<td>&lt; 30</td>
</tr>
</tbody>
</table>

\textsuperscript{108} Some authors note that this is the ‘modern preference’: McBride, above n 23, 628.


\textsuperscript{110} De Florio, above n 64, [4.6.3].

Medium Altitude Long Endurance | MALE | > 500 | 14 000 | 24 to 48 | 1500

Strategic

High Altitude Long Endurance | HALE | > 2000 | 20 000 | 24 to 48 | (4500) 12 000

Special Purpose

Unmanned Combat Aerial Vehicle | UCAV | approx. 1500 | 10 000 | Approx. 2 | 10 000

Offensive | OFF | 300 | 4000 | 3 to 4 | 250

Decoy | DEC | 0 to 500 | 5000 | < 4 | 250

Stratospheric | STRATO | > 2000 | > 20 000 & < 30 000 | > 48 | TBD

Exo-Stratospheric | EXO | TBD | > 30 000 | TBD | TBD

Space | SPACE | TBD | TBD | TBD

Table 3: Classification Scheme Used by UVS International

The terms used in this classification are derived largely from a military – rather than regulatory – perspective and as such the terms speak to capabilities and characteristics that might be expected for a UAS bearing each designation. As with the changing definitions discussed above, it is apparent that the typology of UAS has also evolved as the technology and concepts involved have developed. In that regard, it is apparent that the typology continues to bear the legacy of the dominant military applications. The numerous types and specifications that derive from this military history ‘set the tone of current public debates concerning domestic use and regulation’. The combination of evolving technologies and evolving names has led to a degree of ‘marketing hype’, ‘vendor specific nomenclature’ and an altogether confused typology of UAS. Undoubtedly, this situation will continue as UAS regulations emerge and shape understandings of the technology. Thus, even at a conceptual level, UAS do not interface easily with the existing regulatory system:


113 Bellows, above n 14, 590. See also DeGarmo, above n 42, [1-1], [1-2].


115 Ibid.

116 Yearbook 2015, above n 71, 22 (per ICAO); Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 4.
These frequent recategorizations have contributed to confusion over what is new and what is old, what is revolutionary and what is simply reframed. Unmanned air vehicles have been referred to as both ‘unproven, infant technologies’ and ‘mainstream military weapons’. Given the myriad definitions and concepts available for the term ‘unmanned aerial vehicle,’ both statements are accurate.\(^{117}\)

These issues of terminology and typology therefore present ‘a great challenge’\(^ {118} \) from a regulatory perspective.\(^ {119} \) This challenge is also encountered in attempting to classify UAS, as discussed later in this thesis.\(^ {120} \)

3 *The Market for UAS Technologies*

In Australia, the scope of the potential market for UAS was recognised in 2003 as being one of expected rapid growth and presenting a unique opportunity for Australian industry.\(^ {121} \) As a global phenomenon, recent market studies indicate that the international market for UAS across the defence and civil sectors is likely to be worth approximately $11.5 billion annually by 2024, more than doubling from its present annual value of approximately $6.4 billion.\(^ {122} \) As set out above, the market has been dominated historically by military spending and procurement, which has had a carry-over effect on the development of UAS for civil missions.\(^ {123} \) However, recent projections indicate that with cutbacks to military spending on UAS, the civil market is likely to grow as manufacturers

---


\(^{119}\) See Plucken, above n 46, 18; See generally Weibel and Hansman, above n 47, Ch 4; DeGarmo, above n 42, 1-1, 1-2.

\(^{120}\) See in particular the lack of consensus in the current approaches to classification outlined in Chapter V, and, more specifically, see the discussion of class designations used in the current approaches in Chapter V.C.2 herein.


\(^{123}\) AAIF Report, above n 11, 2; McBride, above n 23, 635.
look to avail themselves of new market opportunities. As such the real enthusiasm lies with the civil market.

The public gains the benefits of UAS technology through their intended applications. There are already a large variety of possible applications for UAS technologies on offer, involving new and unique business cases using smaller and cheaper aircraft than are traditionally present in the aviation industry. These aircraft nonetheless require relatively unrestrained access to public airspace to perform their missions. As set out above, these applications are ‘almost limitless’ and thus regulators can expect that manufacturers and operators will explore almost every possible configuration and performance attribute in search of a market opportunity to exploit in public airspace. The seminal report prepared by the JAA/Eurocontrol UAV Task-Force in 2004 (‘JAA/Eurocontrol Report’) considered the potential applications as falling within 3 categories:

---

124 Teal Group Corporation, above n 122.
125 Many commentators note the significant ‘commercial potential’ of UAS systems: See, eg, Bellows, above n 14, 595; However see AAIF Report, above n 11, 2 (the AAIF notes that the commercial possibilities excite many commentators but that the reality is not as optimistic in light of the regulatory hurdles).
126 AAIF Report, above n 11, 6.
127 See Papadales, Basil, ‘Stimulating A Civil UAV Market in the United States’ (Working Paper, Moire Incorporated, August 2003), 2. Note that this source is not generally available, but a similar analysis (that is, that UAS may compete with conventional aviation as well as compliment it, can be found in Newcome, above n 26, 127-132). Benjamin Kapnik, ‘Unmanned but Accelerating: Navigating the Regulatory and Privacy Challenges of Introducing Unmanned Aircraft into the National Airspace System’ (2012) 77 Journal of Air Law and Commerce 439 provides an interesting observation on the variety of applicants under the COA process in the United States, noting that ‘[e]ntities with active licences include universities, federal agencies, local police departments, and branches of the military. These entities vary in size, ranging from the US Army to the City of Herington, Kansas, which in 2010 had a population of 2,526...The FAA also disseminated a list of thirteen manufacturers that had applied for licences to test unmanned aircraft...The manufacturers include industry heavyweights like Raytheon Co., Bell Helicopter Textron Inc., and Honeywell International.’: at 446-447.
128 AAIF Report, above n 11, 2; Papadales, above n 127, 6.
129 AAIF Report, above n 11, 2; Michaelides-Mateou and Erotokritou, above n 27, 113. See also Bellows, above n 14, 587; Plucken, above n 46, 13.
130 Bellows, above n 14, 595. In a survey of various UAS stakeholders, 65 per cent considered market opportunity to be a primary driver of UAS technology assuming airspace access was available: See Brian Argrow, Elizabeth Weatherhead and Eric W Frew, ‘Real-Time Participant Feedback from the Symposium for Civilian Applications of Unmanned Aircraft Systems’ (2009) 54(1) Journal of Intelligent & Robotic Systems 87, 102.
131 JAA/Eurocontrol Report, above n 59. Prior to the formation of the European Union, the JAA had the responsibility for aviation safety across Europe. This responsibility now falls to its successor, EASA. Eurocontrol is Europe’s airspace management authority.
132 It may also be thought that the market for commercial UAS operations involves UAS undertaking applications that can be performed by conventional aircraft but which UAS can perform at lower cost, and
(a) ‘Technology induced applications’\(^{133}\). These applications involve the provision of services that cannot be performed by conventional aircraft, such as the package delivery services proposed by Amazon and Google,\(^{134}\) which must be small, relatively fast and highly manoeuvrable. Such applications are likely to involve UAS-AC with a mass of <50kg operating at altitudes below approximately 1000ft AGL. Applications for these aircraft were by JAA/Eurocontrol projected to emerge in the short to medium term (considered to be between 2006 and 2010, at the time);\(^{135}\)

(b) ‘Platform induced applications’\(^{136}\). These applications more closely approximate those services performed by conventional aircraft (for instance, crop spraying, banner towing, coastal surveillance).\(^{137}\) Such applications are likely to involve the operation of an aircraft between 600kg and 2000kg, and altitudes up to 20 000ft. Applications for these aircraft were projected by JAA/Eurocontrol to emerge primarily in the medium to long term (considered to be between 2007 to 2011 at the time);\(^{138}\) and

(c) ‘Service induced applications’\(^{139}\). These applications correlate more closely with those presently performed by satellites; for instance, UAS may be used to provide geostationary services such as traffic or weather monitoring or internet relay to remote areas. Such applications are likely to involve the operation of aircraft between 5000kg and 30 000kg, and altitudes up to 90 000ft. Applications for these aircraft were projected by JAA/Eurocontrol to emerge primarily in the long term (considered to be between 2010 and 2011 at the time).\(^{140}\)

It can be said that the current state of the market is well behind the milestones projected by JAA/Eurocontrol. It seems a commercial market in the true sense is still some time

\(^{133}\) JAA/Eurocontrol Report, above n 59, 4.

\(^{134}\) R Marsh, above n 28; Barr, above n 28.

\(^{135}\) JAA/Eurocontrol Report, above n 59, 4.

\(^{136}\) Ibid 5.

\(^{137}\) See for instance Kaiser, ‘Legal Aspects of UAVs’, above n 83, 345.

\(^{138}\) JAA/Eurocontrol Report, above n 59, 5.

\(^{139}\) Ibid 6.

\(^{140}\) Ibid.
This is largely a function of the fact that current UAS regulations do little to facilitate investment and commercial operation. Without coherent and facilitative regulation, many beneficial and legitimate applications may be inhibited or prohibited, thereby denying the public the benefits of those operations. The state of UAS regulation is discussed in the next section.

B Developments in UAS Regulation

The market pressures discussed above have brought about rising numbers and types of regulations for UAS, with regulations being developed in Australia, Canada, Europe, the UK and US and many other places. However, only 1 of these jurisdictions (Australia) actually has UAS regulations (that resemble regulations for conventional aircraft) in force at the time of writing. As it stands, there are no regulations in force in any of these jurisdictions that in fact allow regular, commercial UAS operations.

UAS appear to have been first ‘regulated’ at an international level in 1944 by way of art 8 of the Chicago Convention, and the regulation agenda for UAS has been the subject of increasingly closer scrutiny for approximately the last decade. There are now countless working groups, projects and industry action groups all working on the problem, too. In the circumstances, the fact that no final, substantive regulation has been forthcoming speaks volumes about the difficulties encountered by the regulators. This section provides a brief analysis of the regulatory situation globally; it also serves as an overview of the primary legal sources and legal opinions that are considered in this thesis as regards the important issue of classifying UAS. It is necessary to traverse the current status of the regulatory agenda in order to illustrate how the classification issue arises.

---

141 McBride, above n 23, 637.
142 See the further discussion on this point in Chapter III.D.
143 Note that Australia’s UAS regulations are seen to be provisional and subject to review: See, eg, Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1005, 1006; See James Coyne, ‘UAS Regulatory Developments’ (Discussion Paper, Civil Aviation Safety Authority, Undated), 3 <http://www.icao.int/Meetings/UAS/Documents/Coyne-James_CASA_Australia_WP.pdf>.
1 Growth of Regulatory Agenda for UAS Globally

The volume of the regulatory work underway globally in relation to UAS is phenomenal. It is beyond the scope of this thesis to cover the full breadth of this work, save to note the general status of the ICAO, Australian, Canadian, European, UK and US proposals. This section provides an overview of each.

The ICAO represents the peak body for the safety regulation of aircraft globally, having been established by the Chicago Convention. Until recently, the ICAO has left much of the work on UAS regulations to the regulators and has not issued substantive rules for UAS certification. Rather, the ICAO focused on facilitating development through its UAS Study Group (‘UASSG’), comprising key members and experts drawn from amongst the regulators and their personnel. Established in 2006, the UASSG published important guidance material in the form of Circular 328 in 2011, which clarifies that the regulators have responsibility for regulating UAS as aircraft. In 2014, the ICAO established an RPAS Panel in place of the UASSG. The ICAO also published the ‘Manual on Remotely Piloted Aircraft Systems (RPAS)’ (‘RPAS Manual’) this year, which provides more detailed guidance to the regulators as to the ICAO’s expectations in terms of the shape of UAS regulations.

Prior to the issue of this guidance, the regulators developed and introduced their own regulations; notably in 2002 Australia became the first to introduce regulations specific to UAS in form of CASR Part 101. The regulations establish weight brackets for UAS-AC of < 200g (Micro), < 150kg (Small) and ≥ 150kg (Large). While Micro UAS-AC

---

144 See generally Plucken, above n 46, ch 3.
145 Ibid 61-63.
146 Ibid.
148 Yearbook 2015, above n 71, 23 (per ICAO).
149 RPAS Manual, above n 54.
150 See Yearbook 2015, above n 71, 22 (per ICAO). It is beyond the scope of this thesis to consider the full ramifications of the RPAS Manual, which was released at a late point in time in relation to the completion of this thesis.
151 CASR Part 101 has been described as the ‘envy of the world’: Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1005
152 CASR Part 101 in fact still refers to ‘UAVs’: CASR Part 101 reg 101.240.
are largely exempt, small and large UAS-AC may operate subject to restrictions including the need to stay beneath 400ft altitude and away from controlled airspace, aerodromes and populous areas.\textsuperscript{153} Operations beyond these parameters require an approval from CASA and only UAS issued with certificates of airworthiness may operate over populous areas. All Large UAS-AC must be certificated in the restricted or experimental category.\textsuperscript{154} However, as there are no design standards this requirement essentially precludes the use of the regulations to achieve such operations (on a routine basis);\textsuperscript{155} if they are to occur, it is by way of bespoke design standards agreed by negotiation with CASA.\textsuperscript{156} In reality, commercial UAS operations occur primarily in restricted or specified areas.\textsuperscript{157} Though ground-breaking, \textit{CASN Part 101} was developed at a time when regulators had little experience in regulating UAS – \textit{CASN Part 101} was a ‘first take’ and does not enable routine commercial UAS operations,\textsuperscript{158} nor provide any substantive guidance to industry.\textsuperscript{159} In practice, CASA presently relies on its operational approval processes more so than the airworthiness aspects of \textit{CASN Part 101}.

In Canada, TC commissioned its own study group in 2007 which issued a final report on the proposed integration of UAS that year.\textsuperscript{160} Presently, Canadian regulations require all UAS operations to be approved via the SFOC policy.\textsuperscript{161} This is a ‘safety target’ approach that considers applications on a case-by-case basis,\textsuperscript{162} without specifying any design standards.\textsuperscript{163} However, a number of exemption categories have been established as of November 2014.\textsuperscript{164} The current Canadian system distinguishes commercial and private

\textsuperscript{153} Civil Aviation Safety Authority, ‘Unmanned Aircraft and Rockets’ (Advisory Circular, No AC 101-1(0), Civil Aviation Safety Authority, July 2002), 16. (‘AC 101-1(0)’).

\textsuperscript{154} Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 27.

\textsuperscript{155} \textit{AAIF Report}, above n 11, 6; Maddalon, \textit{Perspectives on Unmanned Aircraft}, above n 8, 26.

\textsuperscript{156} Coyne, above n 143, 4; Maddalon, \textit{Perspectives on Unmanned Aircraft}, above n 8, 26.

\textsuperscript{157} Clothier et al, \textit{Definition of Airworthiness Categories, above n 3, 2.

\textsuperscript{158} \textit{AAIF Report}, above n 11, 6; Clothier et al, ‘Airworthiness Certification Framework’, above n 49;

\textsuperscript{159} Clothier et al, \textit{Definition of Airworthiness Categories, above n 3, 2.

\textsuperscript{160} Coyne, above n 143, 3; \textit{AAIF Report}, above n 11, 11.


\textsuperscript{162} \textit{Canadian Aviation Regulations}, SOR/96-433, reg 602.41 (‘\textit{Canadian Aviation Regulations}’).

\textsuperscript{163} See Plucken, above n 46, 124. See also Chapter III.E.1 for further information on the safety case approach.

\textsuperscript{164} Ibid 131.

use, and weight brackets of 2kg, 25kg, 35kg and >35kg, with exemptions issued to UAS that can comply with restriction criteria.\textsuperscript{165} By these means, TC approves a reasonable number of UAS operations, including commercial operations,\textsuperscript{166} though noting the strain on its resources in addressing increasing numbers of requests.\textsuperscript{167}

In Europe, the JAA published an early, comprehensive study of the certification of UAS in 2004 in the form of the \textit{JAA/Eurocontrol Report} (mentioned above).\textsuperscript{168} This Report became the basis for subsequent work by EASA in 2005 and 2009 in its Advance Notice of Proposed Amendment and Policy Statement respectively.\textsuperscript{169} The JAA’s work still resonates amongst the current approaches to UAS regulation – for instance, the JAA developed a number of ‘guiding principles’ for developing regulation, one of them being the often cited need for UAS to display ELOS.\textsuperscript{170} However, EASA’s work is ongoing, releasing in March 2015 its ‘Concept of Operations for Drones’ (‘ConOps Proposal’) which outlines a 3-tiered system of operations (‘open’, ‘specified’ and ‘certified’) developed on a risk management basis, though no certification standards have been developed.\textsuperscript{171} EASA approved the first large UAS flight in open European airspace in 2013 when a remotely piloted Jetstream 31 flew in non-segregated airspace together with commercial traffic, from Lancashire in England to Inverness in Scotland.\textsuperscript{172} EASA intends to rollout further guidance in late 2015 with a view to opening the skies to UAS in 2016.\textsuperscript{173}

\textsuperscript{166} Plucken, above n 46, 124.
\textsuperscript{168} JAA/Eurocontrol Report, above n 59.
\textsuperscript{170} JAA/Eurocontrol Report, above n 59, 12-13.
\textsuperscript{172} Michaelides-Mateou and Erotokritou, above n 27, 1.
\textsuperscript{173} Eurocontrol, above n 34.
In the UK, the CAA developed early policies for UAS in the form of its guidance document known as ‘CAP722’\(^{174}\) in 2002 (one of the first UAS policies developed globally)\(^{175}\) and a policy for the operation of light UAS in 2004.\(^{176}\) These instruments have been extremely influential in subsequent work, particularly given the use of kinetic energy metrics to correlate UAS with ‘equivalent’ model aircraft, so as to afford some UAS a similar degree of latitude to that granted to model aircraft. The CAA is responsible for sub-150kg MTOW UAS-AC by virtue of EU regulation, and utilises weight brackets of <20kg, and 20 to 150kg; the guidance for each class is contained in CAP722.\(^{177}\) For the sub-20kg classes, UAS-AC are not required to obtain airworthiness certification but are subject to operational restrictions (including the conduct of commercial work with permission) and airspace prohibitions.\(^{178}\) UAS-AC above 20kg (but below 150kg) are required to obtain airworthiness certification or permits to fly, but may be eligible for exemption by the CAA subject to operational approvals are determined by reference to the ‘Concept of Operations’ philosophy which categorises UAS operations according to the risk levels evident in the technical and operational complexity of the proposed operation, akin to a safety case approach.\(^{179}\) These changes were introduced in March 2015 coincident with the roll-out of EASA’s ConOps Proposal.\(^{180}\)

In the US, the FAA has not as yet issued formal regulations, for many years dealing with UAS operations by certifying governmental UAS (military and civilian) as exempt from certification via a ‘certificate of authorisation or waiver’,\(^{181}\) or otherwise by issuing ‘experimental airworthiness certificates’ for private operations.\(^{182}\) However, the FAA

---


\(^{175}\) Michaelides-Mateou and Erotopkritou, above n 27, 119

\(^{176}\) D R Haddon and C J Whittaker, ‘UK-CAA Policy for Light UAV Systems’ (Policy Paper, United Kingdom-Civil Aviation Authority, 28 May 2004).

\(^{177}\) Note as well that an operational distinction made by the CAA between UAS-AC that are between 0 to 7kg, and 7 to 20kg: CAP722, above n 174, 39. See also in relation to EC Regulations, Kaiser, ‘UAVs and Their Integration’, above n 46, 160 n 10; Kaiser, ‘Legal Aspects of UAVs’, above n 83, 355-356.

\(^{178}\) CAP722, above n 174, 25.

\(^{179}\) Ibid. See below Chapter III.E.1 for further information relation to safety case and safety target methods of proposed regulation.

\(^{180}\) CAP722, above n 174, 11.

\(^{181}\) Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 11, 12; See also Bellows, above n 14, 600-601; Plucken, above n 46, 67-69, 114-118 (in relation to experimental certification).

\(^{182}\) This is the only legal route for commercial UAS operations in the US: Bellows, above n 14, 601 n 122.
oversees one of the most active UAS markets. Thus, despite some notable operational progress, the FAA procedures have been criticised for various reasons, including the:

(a) lack of transparency;
(b) need for prolonged planning periods prior to operations; and
(c) fact that the current procedures do not permit routine UAS operations, nor allow any worthwhile or beneficial operations by commercial UAS operators.

As mentioned above, the FAA has also faced legal challenges to its authority to regulate UAS through the use of its policy documents, and although it has commissioned various studies including by the American Society for Testing and Materials International (‘ASTM International’) and the Radio Technical Commission for Aeronautics (‘RTCA’), and created its own study group in the Small UAS Aviation Rulemaking Committee (‘sUAS ARC’), its progress has been delayed.

A more recent initiative by US Congress has sought to ‘jump start’ what had become a somewhat protracted state of development for UAS regulations. In 2012, US Congress enacted the FAA Modernization and Reform Act 2012 (US) (‘FMRA’), which specifically required the FAA to:

(a) develop a comprehensive UAS integration plan within 270 days of ratification of the FMRA. The plan must contain operating and certification standards, sense and avoid capability and operator licencing.

---

183 See the Overview (Chapter I) with respect to the use of Predator UAS to patrol the US-Mexico Border as well as NASA’s civil programmes.
184 DeGarmo, above n 42, 1-5.
185 See, eg, Josef J Vacek ‘Civilizing the Aeronautical Wild West’ (2011) 23(3) Air & Space Lawyer 1, 19; Weibel and Hansman, above n 47, 17.
186 See, eg, Vacek, above n 185, 19; Weibel and Hansman, above n 47, 17; Plucken, above n 46, 114, 115 Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111, 325.
187 In 2011, the FAA took enforcement action against Raphael Pirker, a drone pilot fined US$10000 by the FAA for an incident occurring on a university campus. After a judge originally ruled the FAA’s policy was not a sufficient basis for the fine, the matter was overturned on appeal and ultimately settled. See Stephen Pope, ‘FAA Settles Landmark Pirker UAV Case’ (27 January 2015) Flying Magazine (online) <http://www.flyingmag.com/news/faa-settles-landmark-pirker-uav-case>.
188 FMRA §§ 332(a)(1), 334(a); Bellows, above n 14, 603 n 140.
189 FMRA § 332(a)(2)(A); Bellows, above n 14, 603.
(b) complete (according to the plan) the full integration of civil (non-public) UAS by end of September 2015, and implement standards for public UAS by the end of December 2015;

(c) issue a Notice of Proposed Rule Making (‘NPRM’) in relation to civil (non-public) operations in the National Airspace System within 18 months of submission of the plan to Congress, with a final rule to be published not later than 16 months after that notice has been published, and

(d) produce a final rule on small UAS that will allow for civil (non-public) operation in the national airspace, and

(e) establish 6 test ranges for UAS around the US within 180 days of enactment of the FMRA.

Despite some progress, the FAA missed most of these milestones, and the FMRA has faced criticisms and interpretational difficulties. Although the FAA delivered the ‘Integration Plan’ in 2013 and published its NPRM in relation to small UAS in February 2015 (‘FAA NPRM’), it did not achieve ‘full integration’ of UAS by September 2015.

2 UAS Continue to be Regulated by Exemption

The fact remains that none of the regulations proposed or in force in the jurisdictions assessed provided a positive regulatory pathway that would allow UAS operations in civil airspace for commercial purposes. Rather, all jurisdictions discussed above deal with UAS

190 FMRA § 332(a)(3); Bellows, above n 14, 602, 603.
191 FMRA § 334(b); Bellows, above n 14, 603.
192 FMRA § 332(b); Bellows, above n 14, 604.
193 FMRA § 332(b)(1); Bellows, above n 14, 604.
194 FMRA § 332(c).
195 Michaelides-Mateou and Erotokritou, above n 27, 120.
196 See, eg, Michaelides-Mateou and Erotokritou, above n 27, 120; Takahashi, above n 21, 532. Takahashi notes, for instance that the ‘most important flaw in the [FMRA] is that it directs the FAA to authorize the operation of drones by mass waiver. This represents a form of public policy repudiated seventy years ago’: Takahashi, above n 21, 532.
197 See, eg, Michaelides-Mateou and Erotokritou, above n 27, 120; Bellows, above n 14, 558.
199 FAA NPRM, above n 147. However, it should be noted that the actual rules to be established for small UAS are not likely to be forthcoming for several years: Yearbook 2014, above n 167, 16 (Per FAA).
200 ‘Full integration’ by September 2015 was essentially mandated by FMRA § 332.
on a case-by-case basis. Under these regimes, specific UAS are exempted from compliance with airworthiness requirements after being subjected to an individualised assessment of the overall safety of the proposed operation. In that regard the recent changes at Congress level in the US have not altered the fact that UAS continue to be regulated by exemption.\(^{201}\) Rather, a system of ‘mass waivers’\(^{202}\) has been encouraged by Congress, which some have noted to seriously conflict with the underlying basis upon which aviation safety has been maintained to date.\(^{203}\) It is notable, for the purposes of this thesis, that all of the mentioned regulators have cited the challenge of classifying UAS in the course of developing certification rules for UAS.\(^{204}\) At this stage, there is no consensus between them, as set out later in this thesis.

3 Developments towards a Comprehensive Regime for Mainstream UAS Operations

Regulatory developments have been analysed by industry groups and academics over time, emanating most often from technical perspectives such as the safety science and risk management fields. These important contributions have significantly influenced the growth of the regulatory agenda for UAS. This section provides an overview of the relevant and seminal work.

In 2004, Matthew DeGarmo of the MITRE Corporation published a comprehensive study commissioned by the FAA in relation to the integration of UAS into civil airspace.\(^{205}\) The study specifically noted the importance of classification as an area of ‘high legal complexity’.\(^{206}\) The same year, the American Institute of Aeronautics and Astronautics (‘AIAA’) also published a glossary of terms for UAS (then known as UAVs) as a first step in the development of certification standards.\(^{207}\)

\(^{201}\) Takahashi, above n 21, 504.

\(^{202}\) Ibid.

\(^{203}\) Ibid.

\(^{204}\) Coyne, above n 143, 2-4, 7; TC, above n 170, 2; CAP722, above n 174, 28,29; ConOps Proposal, above n 171; FAA NPRM, above n 147, 9556 – 9558; See also RPAS Manual, above n 54, 2-3.

\(^{205}\) DeGarmo, above n 42.

\(^{206}\) Ibid 2-41.

\(^{207}\) AIAA, above n 42, iv.
In 2005, Weibel and Hansman of the Massachusetts Institute of Technology published a detailed study of the safety considerations confronting the use of UAS in civil airspace. The study analyses the importance of classification and develops a prototype classification scheme proposing different operational areas for different types of UAS.\footnote{208}

From there, authors such as Clothier et al (in Australia)\footnote{209} and Dalamagkidis, Valavanis and Piegl (in Europe)\footnote{210} have written extensively about these issues and have generated proposals for studying the risks associated with UAS operations since approximately 2008. Likewise, Fraser and Donnithorne-Tait (in Canada)\footnote{211} have also studied the risks of UAS operations with a focus on proposals to certify and classify UAS in a methodical and logical manner. The Australian Aerospace Industry Forum (‘AAIF’) has developed on Clothier et al’s work and generated a practical analysis of Australia’s regulations from an industry perspective.\footnote{212} The AAIF Report notes the need for a ‘certification regime’ by which certification standards can be established for the different types of UAS in a similar manner to the operation of Part 21 of the regulations for conventional aircraft.\footnote{213} Significant and recent work has also originated in the US through the efforts of NASA and its associated scientists, who have produced some of the most comprehensive studies of UAS classification to date.\footnote{214} The NASA scientists have continually noted the centrality

\footnote{208} Weibel and Hansman, above n 47, ch 3.3.

\footnote{209} Clothier has collaborated with a number of other researchers in relation to UAS since approximately 2006. The following works have been considered for the purposes of this thesis: Clothier and Walker, \textit{Determination and Evaluation of Safety Objectives}, above n 47; Clothier and Walker, \textit{Casualty Risk Analysis}, above n 40; Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22; Palmer and Clothier, above n 36; Clothier, above n 53; Clothier et al, ‘Airworthiness Certification Framework’, above n 49; Clothier et al, \textit{ALARP and Risk Management}, above n 44.

\footnote{210} Dalamagkidis has also written extensively since approximately 2008 in collaboration with Valavanis and Piegl. The following works have been considered for the purposes of this thesis: Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111; Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50.

\footnote{211} C S R Fraser and D Donnithorne-Tait, ‘An Approach to the Classification of Unmanned Aircraft’ (Paper presented at 26th International Conference on Unmanned Air Vehicle Systems, Bristol, United Kingdom, 11-12 April 2011).

\footnote{212} AAIF Report, above n 11.

\footnote{213} Ibid 6. The phrase ‘Part 21’ normally refers to the certification framework contained in \textit{Aeronautics and Space}, 14 Code of Federal Regulations § 21 (2015), also referred to as 14 CFR Part 21 (‘\textit{CFR Part 21}’), and can also be found in, for instance, \textit{CASRs Pt 21}.

\footnote{214} The following works have been considered for the purposes of this thesis: Hayhurst et al, \textit{Unmanned Aircraft Hazards}, above n 11, 2; Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8; Hayhurst, Kelly, Jeffrey M Maddalon, A Terry Morris, Natasha Neogi and Harry A Verstynen, ‘A Review of Current and Prospective Factors for Classification of Civil Unmanned Aircraft Systems’ (Technical Report, NASA/TM-2014-218511, National Aeronautics and Space Administration, August 2014)
of classification to the difficulties encountered in certification, and advocated for consensus on the basic aspects of classification.\textsuperscript{215}

Similarly, the regulatory agenda for UAS has grown to incorporate consideration of the legal issues involved in developing a certification regime for UAS. As set out above, legal issues were initially identified in DeGarmo’s 2004 study, though these issues were not studied by lawyers until Kaiser’s writing in 2006,\textsuperscript{216} followed by his further work in 2011.\textsuperscript{217} Other legal writers have canvased the various legal issues that are implicit in the problem of certifying UAS; for instance, Bellows,\textsuperscript{218} Diederiks-Verschoor,\textsuperscript{219} Gogarty,\textsuperscript{220} Kapnik,\textsuperscript{221} Marshall,\textsuperscript{222} Masutti,\textsuperscript{223} Michaelides-Mateou,\textsuperscript{224} Peterson,\textsuperscript{225} Plucken,\textsuperscript{226} Takahashi,\textsuperscript{227} and Vacek.\textsuperscript{228} In so far as these works deal with the issue of classification this legal writing is considered further in this thesis (as a cross-section of available legal opinion). It is notable that all of the above works deal with the topic of classification with varying degrees of specificity, with several expressly identifying classification as a complex and important matter.\textsuperscript{229}

However, notwithstanding the steady growth in the study of UAS regulation, current proposals have not created a viable pathway for mainstream commercial UAS operations. It is apparent that national regulations have developed sporadically in the absence (until very recently) of guidance from ICAO and, to a certain degree, the FAA and EASA. Each

\begin{flushright}
\textsuperscript{215} See, eg, Maddalon et al, \textit{Considerations of Unmanned Aircraft}, above n 49.
\textsuperscript{216} Kaiser, ‘Legal Aspects of UAVs’, above n 83.
\textsuperscript{217} Kaiser, ‘UAVs and Their Integration’, above n 46.
\textsuperscript{218} Bellows, above n 14, 611.
\textsuperscript{219} I H Ph Diederiks-Verschoor, \textit{An Introduction to Air Law} (Wolters Kluwer, 9\textsuperscript{th} revised ed, 2012), 263.
\textsuperscript{221} Kapnik, above n 12, 442-444.
\textsuperscript{223} Masutti, above n 100, 1.
\textsuperscript{224} Michaelides-Mateou and Erotokritou, above n 27, 121 to 123.
\textsuperscript{225} Peterson, above n 5, 604-608.
\textsuperscript{226} Plucken, above n 46, 25-27, ch 6 B.3.
\textsuperscript{227} Takahashi, above n 21, 513-514.
\textsuperscript{228} Vacek, above n 185, 22.
\textsuperscript{229} See especially Plucken, above n 46, 25, 26, Ch 6 B.3; See also Kaiser, ‘Legal Aspects of UAVs’, above n 83, 345; Kaiser, ‘UAVs and Their Integration’, above n 46, 166 nn 10-11; Peterson, above n 5, 594.
\end{flushright}
have been slow to publish their studies. ICAO’s *RPAS Manual*, for instance, was published 8 years after the need for UAS regulation was flagged as an issue for ICAO.\(^{230}\) Similarly, the FAA has not been able to comply with congressionally mandated milestones which sought to expedite a solution. EASA published early guidance material but the EASA A-NPA published in 2005 did not result in actual law.\(^{231}\) EASA has recently published its *ConOps Proposal* which,\(^{232}\) although setting out a roadmap for operations that differs from prior approaches, is a precursor to actual regulation. In the result, the outcomes that have emerged are not wholly consistent internationally; for instance, ICAO’s *RPAS Manual* provides guidance designed to facilitate and harmonise national regulations on the basis that UAS are aircraft and within the purview of the regulators. On the other hand, the *FMRA* provides for a system of UAS regulation that is predicated on a ‘mass waiver’ or exemption of UAS from compliance with certification rules,\(^{233}\) rather than by providing a means of certifying UAS in a manner consistent with the procedures employed for conventional aircraft.\(^{234}\) The *FAA NPRM* (which seeks to give effect to *FMRA*) proposes to regulate and enable only a portion of the UAS available on the market, and potential operations remain subject to restriction.\(^{235}\) EASA’s *ConOps Proposal* defines a more tailored, risk-based approach that takes account of individual operations but, like the *FAA NPRM*, does not provide any actual pathway to routine UAS use on a broader scale.

This situation has resulted from the base fact that UAS technologies and operations confront the existing safety system, rather than readily conform to it. Given that regulations have not been introduced anywhere in the world that would permit routine access to public airspace for UAS, the regulatory agenda is delayed, as is the full realisation of the many beneficial applications offered by UAS technologies. The next

---

\(^{230}\) ICAO established its UASSG in 2007: See Plucken, above n 46, 54.

\(^{231}\) *EASA A-NPA*, above n 169.

\(^{232}\) *ConOps Proposal*, above n 171.

\(^{233}\) Takahashi, above n 21, 532.

\(^{234}\) Ibid 533. In that sense, it may be thought that the FAA is being required to ‘abrogate’ a traditional function of scrutinising aircraft in order to declare it fit for flight and thus that the terms of the *FMRA* may be ‘legally unsound’: Takahashi, above n 21, 495. Takahashi in particular notes that this may have ‘disturbing long-term policy implications’ for the regulation of UAS: Takahashi, above n 21, 495. That is, the effects of the FMRA essentially declare UAS to be ‘exceptional’ in the sense that they are not going to be afforded the same rights and privileges as conventional aircraft: Takahashi, above n 21, 502; *FMRA §§ 331(2), 333(b).*

\(^{235}\) See, eg, *FAA NPRM*, above n 147, p9456.
Chapter II

Chapter examines the ways that UAS technologies confront the existing system, with particular emphasis on the difficult problem of airworthiness certification for UAS.
III UAS TECHNOLOGIES CONFRONT THE EXISTING SAFETY SYSTEM

The simple reference to ‘pilotless aircraft’ in the Chicago Convention has created a number of difficult issues for the regulators nearly 70 years later. The Chicago Convention art 8 states as follows:

Pilotless Aircraft: No aircraft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting State without special authorisation by that State and in accordance with the terms of such authorisation. Each contracting State undertakes to ensure that the flight of such aircraft without a pilot in regions open to civil aircraft shall be so controlled as to obviate danger to civil aircraft. 236

It must have been apparent even then (because it is implied in the words of the above provision) that there were risks involved in flying such aircraft, and that these risks were somehow different than those involved with conventional aviation. 237 It is also apparent that art 8 reflects the continuing understanding that UAS are ‘fundamentally different’ 238 than other aircraft, and that steps needed to be taken to preserve the safety of the system. UAS may be thought to differ in terms of 5 key aspects: technological, performance, operational, social and economic. 239 The risks are different – for instance, not every crash of a UAS-AC will necessarily involve the possibility of injury to a person - there is no person on board. 240 Further, not all of the equipment that is necessary for flight to occur is on-board the aircraft, nor does the aircraft contain all equipment and personnel that can affect the safety of the flight. 241 While the natural ‘pairing of pilot and plane’ 242 underpins the core philosophies of the conventional aviation system, this ‘shared fate’ does not exist.

236 Chicago Convention art 8.
237 Michaelides-Mateou and Erotokritou, above n 27, 115; Plucken, above n 46, 50.
238 Hayhurst et al, Unmanned Aircraft Hazards, above n 11, 3. For a discussion on the historical debate as to whether UAS are ‘aircraft’ within the meaning of art 8 of the Chicago Convention, and the consequences of that question, see Plucken, above n 46, 41-44; Kaiser, ‘UAVs and Their Integration’, above n 46, 162. In fact, many of the issues relating to how UAS are to ‘fit’ into the existing system are caused by the fact that art 8 contemplates that UAS will require a ‘special authorization’ from the States overflown, and the further requirements to ‘obviate danger’ to other aircraft. There remain interpretational questions as to what this requires in terms of a certification regime for UAS and whether something more (or different) than conventional certification is required for airspace access; Kaiser, ‘Legal Aspects of UAVs’, above n 83, 348, 349; Kaiser, ‘UAVs and Their Integration’, above n 46, 162; Plucken, above n 46, 43, 44, 110.
239 Clothier and Walker, Casualty Risk Analysis, above n 40, 1.
240 Maddalon et al, Perspectives on Unmanned Aircraft, above n 8.
241 Ibid.
242 Ibid 3.
for UAS. There is therefore an innate conflict between these philosophies and the essence of unmanned flight. This is explained as central to many of the difficulties facing the regulators later in this Chapter.

On the whole, art 8 – as the centrepiece of regulation for UAS internationally - may be interpreted such that UAS generally must not compromise the safety of conventional aviation which aligns with the requirements of the ELOS mandate. Nonetheless, whilst this thesis doesn’t attempt to resolve the meaning of art 8, from a practical perspective regulators must make routine certification available to UAS in some form, if UAS are to take part in the aviation system as legitimate airspace users. This Chapter overviews the existing safety system to show the ways that UAS confront it.

A Existing System has Evolved Over Time to the Current Level of Safety

The existing safety system has evolved in a manner specific to the technology with which it is primarily concerned – conventional aviation. In the formative years of aviation, the regard for the ‘safety of the aviator and the promotion of commerce were at best tertiary goals. Although the initial safety focus was directed towards risks to the public, with the advent of commercial passenger services the nature of the perceived risks began to change towards a concern for the safety of the passengers, who placed their faith in the pilot and the aircraft. This shift in perception was coupled with advancing technology and increasingly mainstream air transport services; the safety standard expected by the

---

244 See, eg, Plucken, above n 46, 94.
245 Kaiser, ‘Legal Aspects of UAVs’, above n 83, 349; Plucken, above n 46, 41-44.
246 See, eg, AAIF Report, above n 11, 6. This proposition is generally accepted and is consistent with the Chicago Convention, and the clarification issued by ICAO that all UAS are aircraft within the regulatory oversight of the regulators: Circular 328, above n 5, 2 [1.7], 4 [2.5]. But see the approach mandated by the FMRA, which rather (arguably) requires wide-scale waiver of compliance with the requirement for obtaining an airworthiness certificate: see Chapter II.B.2 above. For discussion on the Chicago Convention art 8 see Kaiser, ‘Legal Aspects of UAVs’, above n 83, 348-349; Plucken, above n 46, 41-44.
247 See generally Hayhurst et al, Review of Current and Prospective Factors, above n 214, 3.
248 Takahashi, above n 21, 516.
public gradually increased as a result. With increasing numbers of aircraft in the sky, there also came to be a risk of collision and thus a recognition of the importance of communication and coordination between flights. Given that aviation has been viewed from the outset as a concept international in scope,\(^{250}\) the evolution of a co-extensive, international safety system was inescapable.\(^{251}\)

A treaty-based system has emerged over the course of the last century to address these issues in the face of ongoing technological and operational developments. The *Chicago Convention* – the cornerstone of the safety system – specifies that:

(a) each nation has sovereignty over its own airspace;\(^ {252}\)
(b) each nation must recognise certificates of airworthiness, certificates of competency and licences issued by other member nations;\(^ {253}\) and
(c) the requirements for the issue of certificates of airworthiness, certificates of competency or licences must be equal to or above the minimum standards established by the *Chicago Convention*.\(^ {254}\)

On that basis, maintaining safety within a State’s airspace is therefore the responsibility of the State itself. Safety is an issue at governmental level and it is for the national legislators ‘to determine how safe is safe’.\(^ {255}\) This is viewed primarily as a technical area for the expertise of safety scientists and engineers.\(^ {256}\) However, the question also has important legal dimensions in establishing, reviewing, and enforcing the safety framework, and thus the question of safety is not the sole domain of technical professionals; rather it involves a complex lawmaking process.\(^ {257}\) The existing safety system uses high-level treaty to facilitate the harmonisation of these technical elements. This results in a tiered system of law descending from international treaty to primary, domestic legislation, to numerous

\(^{250}\) Huang, above n 249, 21, 229.
\(^{251}\) Ibid 21.
\(^{252}\) *Chicago Convention* art 1. This thesis does not give full treatment to the breadth of the international regime in relation to bilateral agreements between States for the use of airspace for commercial traffic: See generally Giemulla, ‘Chicago System’, above n 59, 19.
\(^{253}\) *Chicago Convention* art 33.
\(^{254}\) *Chicago Convention* art 33.
\(^{255}\) Huang, above n 249, 8.
\(^{256}\) Ibid 7, 8, 21, 229.
\(^{257}\) Ibid.
levels of technical specifications in the subsidiary regulations.\textsuperscript{258} Each level increases in specificity in terms of practical requirements designed to achieve the safety of the system. Most States therefore convene an authority having the necessary expertise to carry out the regulatory function, for instance, CASA, TC, CAA, FAA, and EASA.\textsuperscript{259}

The \textit{Chicago Convention} system was borne amongst rapid change, and it must continue to cope with such change. In the last 100 years aviation has evolved from a mere spectacle, to a genuine commercial endeavour, to an industry worth billions. The planes themselves have evolved from rickety contraptions to rugged, piston-powered machines, all the way through to jet (and now solar) powered, computer-designed marvels constructed of exotic plastics and composites. Where early aviation was a ‘seat-of-the-pants’ exercise by which ‘the eyes, brain, and finesse of the pilot controlled the aircraft and pushed it to its maximum capabilities’, \textsuperscript{260} modern commercial pilots have become ‘managers’ of the aircraft to a significant degree, having far less direct control of the aircraft than in days gone by. \textsuperscript{261} The effects of the trend are visible in the cockpit: a bloom of buttons and switches have taken hold and LCD displays have replaced dials made of ‘brass, jewels and leather’. \textsuperscript{262} These effects are visible not only in the aircraft itself; automation has resulted in ‘the reduction of the flight deck crew from five down to two individuals’. \textsuperscript{263} Automation has delegated traditionally human flight functions to hardware and software.

As a result of all of this change, the existing laws have developed in a somewhat ad hoc fashion, and traditionally in a reactive way, by which accidents have been investigated, lessons learned, and the regulatory requirements supplemented in an effort to preclude similar, future incidents.\textsuperscript{264} Modern approaches to safety regulation, however, have developed procedures and precedents for dealing with new aviation technologies in more

\begin{flushright}
\textsuperscript{258} Ibid 43. \\
\textsuperscript{259} Several commentators have noted the importance of ‘expertise’ or ‘competence’ in ensuring an effective regulatory system: See, eg, Ronald I C Bartsch, \textit{Aviation Law in Australia} (Thomson Reuters, 3\textsuperscript{rd} ed, 2010) 108; See generally Robert Baldwin, Martin Cave and Martin Lodge, \textit{Understanding Regulation} (Oxford University Press, 2\textsuperscript{nd} ed, 1999), 80 (‘Understanding Regulation’). \\
\textsuperscript{260} Schultz, above n 81, 13. \\
\textsuperscript{261} Hayhurst et al, above n 11, 2, 3. See generally Nas, above n 79, 13-15. \\
\textsuperscript{262} Takahashi, above n 21, 529. \\
\textsuperscript{263} Kaiser, ‘UAVs and Their Integration’, above n 46, 165. \\
\end{flushright}
methodical, proactive, and risk-sensitive ways. This approach is explained further in the next section with regard to the specific role of airworthiness certification in the safety system.

B Certification of Aircraft: A Fundamental Component of the Existing System

The modern aviation system ensures safety in 3 fundamental ways – by regulating pilot, airspace and aircraft (sometimes called the ‘three pillars’ of the safety system). There are real questions as to how UAS might interface with each pillar; however, the focus of this thesis is on the certification of aircraft as a perplexing issue facing the integration of UAS into the existing aviation system. Aircraft certification has played a particularly important role in ensuring the safety of the system and is central to the Chicago Convention regime. Pursuant to that regime, certificates of airworthiness must be issued to civil aircraft before they can be flown in a State’s airspace, and each State must recognise certificates issued in other States, creating a relatively harmonised international system. The basic airworthiness standards to be met are set out in annex 8 of the Chicago Convention. Thus, although the Chicago Convention governs international flight, it also promotes harmonisation between national regulations and therefore the

---

265 See generally Takahashi, above n 21, 527 n 284; JAA/Eurocontrol Report, above n 59, 17; Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50, 510; De Florio, above n 64, 52. The modern system embraces the concept of a ‘safety system’ that requires continual review of all aspects of the aviation system and the progressive implementation of new rules and new technologies so as not to disturb the safety of the system. This is discussed further in Chapter III.C.

266 De Florio, above n 64, 1; Takahashi, above n 21, 517; See Alan Simpson, Vicky Brennan and Joanne Stoker, ‘UAS Safety in Non-Segregated Airspace’ in Thanh Mung Lam (ed) Aerial Vehicles (InTech, 2009), 638. Others have identified additional or alternative pillars or elements: See Huang, above n 249, 42-43; JAA/Eurocontrol Report, above n 59, 16.

267 Noting that there is a blurring of the lines between these traditional pillars when it comes to UAS: See, eg, Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 16; AAIF Report, above n 11, 7.

268 See in relation to issues concerning airspace and pilot regulation, DeGarmo, above n 42, 2.3, 2.51 respectively; See also Kaiser, ‘Legal Aspects of UAVs’, above n 83, 352; Plucken, above n 46, 32, 33.

269 See generally JAA/Eurocontrol Report, above n 59, 17 – 19.

270 Plucken, above n 46, 104; Chicago Convention art 31.


272 Annex 8 relates to Definitions (Part I), Procedures for Certification and Continuing Airworthiness (Part II), Large Aeroplanes (Part III), Helicopters (Part IV), Small Aeroplanes (Part V), Engines (Part VI) and Propellers (Part VII). See generally Plucken, above n 46, 104, 105.
requirement for airworthiness certification provides a practical basis for domestic flight regulation.\textsuperscript{273}

Airworthiness can be defined as

\begin{quote}
a concept, the application of which defines the condition of an aircraft and supplies the basis for judgement of the suitability for flight of that aircraft, in that it has been designed, constructed, maintained and is expected to be operated to approved standards and limitations, by competent and approved individuals, who are acting as members of an approved organisation and whose work is both certified as correct and accepted…\textsuperscript{274}
\end{quote}

The States must formulate their own ‘codes’\textsuperscript{275} of airworthiness requirements in implementing Annex 8, though efforts are made to harmonise requirements.\textsuperscript{276} The requirements are referred to informally as ‘codes’ because they contain a high level of particularity dealing with most aspects of the design, construction and maintenance of the aircraft.\textsuperscript{277} Out of practice, a system has arisen involving 3 related levels of certification:

(a) certificates of airworthiness issued to individual aircraft;
(b) a type certification scheme whereby aircraft designs can be approved as compliant with the codes such that the same aircraft can be replicated and individual units issued with a certificate of airworthiness; and

\textsuperscript{273} See Maneschijn et al, above n 42, 346-347; De Florio, above n 64, 6 [3.1.1]. Diederiks-Verschoor notes as well that notwithstanding UAS operations are largely a domestic concern and therefore outside the remit of the Chicago Convention, at an international level it has been recognised that UAS must comply with the same safety and operational standards as conventional aircraft: Diederiks-Verschoor, above n 219, 261. Harmonisation between international approaches also provides a compelling reason to pursue an ‘internationally accepted design code for UAVs’: Kaiser, ‘Legal Aspects of UAVs’, above n 83, 355. See also Timothy M Ravich, ‘The Integration of Unmanned Aerial Vehicles into the National Airspace’ (2009) 85 North Dakota Law Review 597, 618-619.

\textsuperscript{274} See Clothier et al, Definition of Airworthiness Categories, above n 3, 1, quoting Australian Government, ‘Defence Instruction (general) ops 02-2’ (Australian Defence Force Airworthiness Management Directive, Department of Defence, Canberra, 2002); See also Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 2.

\textsuperscript{275} JAA/Eurocontrol Report, above n 59, 17.

\textsuperscript{276} See De Florio, above n 64, 8, 42, 6 [3.1.1]; JAA/Eurocontrol Report, above n 59, 19. This involves the use of Standards and Recommended Practices (‘SARPs’) issued by the ICAO and built into annex 8 and other guidance material. Under art 37 of the Chicago Convention, the States are required to follow give notice of deviation from ICAO stipulations under art 38 in certain circumstances: See generally Giemulla, ‘Chicago System’, above n 59, 38-39; Plucken, above n 46, 104, Huang, above n 249, 43, 44.

\textsuperscript{277} Plucken notes that annex 8 is over 200 pages long: Plucken, above n 46, 106; See Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 872.
(c) production certification signifying that the manufacturer is authorised to produce duplicate aircraft under the approved design.\textsuperscript{278}

Each aspect is concerned with ensuring that individual aircraft are approved as ‘safe’ by reference to the codes. These codes have been amended and supplemented over time as the investigation of accidents provided new information as to potential hazards, which turn led to changes in the standards.\textsuperscript{279} The codes represent a compilation of the lessons learned over time – as such,\textsuperscript{280} adherence to the ‘pre-defined’, specific requirements set out in the codes is an assurance that the aircraft is safe in its operation.\textsuperscript{281} The aircraft manufacturer has the burden of proving compliance;\textsuperscript{282} thus in general terms, the codes serve to ensure that the equipment comprising the aircraft (and thus the aircraft as whole) is reliable.\textsuperscript{283}

This system of certification has become intrinsic to the assurance of safety by the regulators:

Since 1926, the federal [US] government has issued several different certificates. The government may issue a ‘type certificate’ to the ‘designer of an aircraft (or [a] component part thereof) certifying that the type (or component), as represented by authenticated data in the form of specifications, descriptions, and drawings… has been found to be suitable as a basis for the manufacture of airworthy aircraft… constructed in accordance with such data.\textsuperscript{284}

In this way, the codes speak to the ‘fitness’ of the aircraft to fly, but say nothing about what the aircraft is to be used for or where they fly.\textsuperscript{285}

The usage of this regime has resulted in a system of classification and categorisation of aircraft.\textsuperscript{286} Given that the Chicago Convention system requires the States to adopt and

\textsuperscript{278} Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 2
\textsuperscript{279} Bartsch, above n 259, 548; Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 5; De Florio, above n 64, 6 [3.1.1].
\textsuperscript{280} Hayhurst et al, \textit{Review of Current and Prospective Factors}, above n 214, 3.
\textsuperscript{281} See Plucken, above n 46, 93; Takahashi, above n 21, 529; De Florio, above n 64, 8.
\textsuperscript{282} Takahashi, above n 21, 498, 499.
\textsuperscript{283} De Florio, above n 64, 6 [3.1.1].
\textsuperscript{284} Takahashi, above n 21, 523.
\textsuperscript{285} See, eg, Plucken, above n 46, 94; Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 14; Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 2; Kaiser notes specifically that ‘[i]n the context of air law, the purpose of the vehicle, is normally not considered a criterion’: Kaiser, ‘Legal Aspects of UAVs’, above n 83, 345.
\textsuperscript{286} The terms ‘categorisation’ and ‘classification’ are used interchangeably in the literature, see for instance Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 4, 6; Clothier, above n 53, 4. See the
develop prescriptive and detailed codes of requirements, and that different aircraft will of course necessitate different requirements,\textsuperscript{287} the identification of classes of aircraft that are ‘as “homogenous” as possible’\textsuperscript{288} has resulted in the existing system. Conventional aircraft are therefore classified into a small number of classes according to aircraft mass, configuration, type of operation, engine type and number, and the number of passengers carried.\textsuperscript{289} In that regard, the existing system ‘partitions’\textsuperscript{290} standard fixed-wing aircraft into categories to which certification standards attach: normal, utility, aerobatic, or commuter requiring certification under for instance the FAR 23 standards,\textsuperscript{291} with large or transport aircraft being certified under FAR 25.\textsuperscript{292} Discrete airworthiness standards therefore apply to each class.

Essentially, the regime internationally comprises of a ‘certification regime’\textsuperscript{293} or a general ‘structure’\textsuperscript{294} that specifies the types of certificates available to civil aircraft and the precise criteria, standards and recommended practices applicable to each type of certificate.\textsuperscript{295} Occasionally new classes are inducted into the regime and new standards are needed. This process of developing standards has been described as follows:

\textsuperscript{287} De Florio, above n 64, 48; Hayhurst et al, \textit{Review of Current and Prospective Factors}, above n 214, 3.
\textsuperscript{288} De Florio, above n 64, 48; Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 4. Clothier et al note that type categories of aircraft that are ‘similar in some relevant way’: Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 4. Furthermore, Clothier et al note separately that ‘ [a type category]…is essentially a homogenous grouping of aircraft types and models of generally similar characteristics, based on the proposed or intended use of the aircraft, and their operating limitations’: Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 873.
\textsuperscript{289} Weibel and Hansman, above n 47, 36; Kaiser, ‘Legal Aspects of UAVs’, above n 83, 345; Takahashi, above n 21, 521; Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 14. Note also that standard and special certification is available. The former is the most relevant to this thesis as standard certification entitles the aircraft operator to relative freedom of flight where the latter is ordinarily subject to operation restriction, though special certification may also be appropriate for UAS: Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 8; Hayhurst et al, \textit{Review of Current and Prospective Factors}, above n 214, 3.
\textsuperscript{290} Hayhurst et al, \textit{Review of Current and Prospective Factors}, above n 214, 3.
\textsuperscript{291} See above n 213 in relation to the FARs, noting the equivalent regulations in the other jurisdictions, for instance the \textit{Civil Aviation Safety Regulations 1988} (Cth), and the CS): see De Florio, above n 64, 48.
\textsuperscript{292} De Florio, above n 64, 48; Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 3, 8.
\textsuperscript{293} AAIF Report, above n 11, 6, 11.
\textsuperscript{294} In conventional aviation regulations, the structure is set out in \textit{CFR Part 21}, which provides for the issue of type certificates in the primary or restricted category, and the issue of certificates for the specific kinds of aircraft in Subpart H; Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 1.
\textsuperscript{295} The technical aspects fall within the overall legal structure: Huang, above n 249, 7; Masutti, above n 100, 5; See also Maneschijn et al, above n 42, 345, 346.
We must not infer that the airworthiness standards are different because the transport aeroplanes should be safer than other types of aircraft. Safety must be maximised for all aircraft, taking into account the criteria of ‘practicability’… As a fundamental concept, simple aircraft should have simple airworthiness standards to comply with.296

The applicable standards are determined on the basis of practicability;297 that is, a balance is struck between maximisation of safety and cost implications due to the severity of the standard.298 This concept is central to discussion of the classification of UAS in terms of understanding the appropriate ‘types’ and ‘treatments’ referred to in Chapter 1 above. Thus, for present purposes, it is enough to note that while the maximisation of safety has primacy against all other considerations (such as economic and financial matters) the ‘reality of life’299 is such that these other matters must be considered. There can be no guarantee of safety; safety can only ever be maximised taking account of the technological state of the art at any given time and the capacity of industry to achieve ongoing safety improvements.300 Thus, at a practical level, these often unmentioned economic factors are still observable in the Chicago Convention system and remain relevant for the purposes of certification.301

C Existing System is Acceptable to the Public and Flight Freedoms Granted

Traditionally, aviation has been an ‘inherently dangerous activity’.302 As such the regulators cooperate under the auspices of the Chicago Convention regime towards an ever-improving level of safety in aviation globally.303 The system has now developed to such a level that it has to be considered whether aviation still remains ‘inherently dangerous’.304 When it comes to incorporating a new technology such as UAS into this system, the question arises as to the level of safety that must be maintained.305 ICAO, for

296 De Florio, above n 64, 48.
297 Ibid. The term ‘affordability’ may also be used: Huang, above n 249, 54.
298 De Florio, above n 64, 47.
299 Huang, above n 249, 54.
300 Ibid.
301 Ibid.
302 Takahashi, above n 21, 499.
303 JAA/Eurocontrol Report, above n 59, 19; Clothier and Walker, Determination and Evaluation of Safety Objectives, above n 47; Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1006.
304 Takahashi, above n 21, 499; See eg Kaiser, ‘UAVs and Their Integration’, above n 46, 161.
305 See generally Clothier and Walker, Determination and Evaluation of Safety Objectives, above n 47.
instance, noted ‘aviation safety’ as being the ‘state of freedom from unacceptable risk of injury to persons or damage to aircraft and property’. The FAA defines ‘safe’ as generally ‘denoting an acceptable level of risk of, relative freedom from, and low probability of harm’. Thus the concept of safety is necessarily bound up with that of risk. However, in essence, the system cannot be free of all risk; what is being sought instead is a freedom from avoidable risks, and thus the maintenance of safety in the modern system has become more or less an exercise in risk management. This risk management exercise is a ‘whole of system’ approach that encompasses all aspects of aviation through the ‘three pillars’ of safety (as described above).

Knowledge of the relevant risks has been pivotal in developing the modern aviation system to its present position. As set out above, the modern system has been shaped tremendously by specific events, mainly accidents that have thrown light on certain risks or hazards. By that means, changes in laws and standards are made after the fact in order to increase safety and prevent the same thing from happening again. This in turn led to technological and safety improvements being made to meet the changes to the requirements:

For conventional human-piloted aviation, risk management strategies have taken the form of a prescriptive body of regulations. There is a great deal of heritage in these regulations which have evolved over a century of experience in the hazards of human-piloted aviation. This approach can be described as a ‘tombstone policy’, were the lessons learned from mishaps are progressively incorporated into the regulation of the hazardous activity.

308 Clothier, Fulton and Walker note that ‘the concept of safety and its management will always embody divergent perspectives and elements of subjectivity, potentially leading to the inappropriate or the ineffective management of the risks’: above n 22, 1006. See also Bartsch, above n 259, 547.
309 See Huang, above n 249, 6; Bartsch, above n 259, 548.
310 Bartsch, above n 259, 566.
311 See above n 266. Noting that the ‘3 pillars’ concept may be too simplistic but nonetheless provides a useful concept for the purposes of this thesis.
312 Clothier and Walker, Casualty Risk Analysis, above n 40, 1.
In this fashion, there has been an observable trend in the changing risk philosophies underpinning the safety system over time. Most importantly, the modern system has abandoned the historical ‘tombstone policy’ in favour of a far more rigorous, risk-managed approach. This approach focuses on safety as a ‘systemic’ issue – that is, safety is affected by activities on the ground as well as in the air. Thus the modern system embraces a methodical approach to safety favouring rigorous analysis, repeated testing and constant review. This coincides with the movement towards the adoption of a ‘precautionary principle’ in aviation regulation whereby regulators restrict the impact of new elements in the system until proven safe. The adoption of this philosophy is consistent with its broader uptake internationally and in other regulatory areas, in recognition of an increasing ‘risk awareness’ in modern society. The incorporation of new technologies must therefore be approached delicately. Pursuant to these safety concepts, new technologies and aircraft take significant periods of time to develop and then ‘trickle only slowly into market-ready aviation products’. Proceeding in this fashion has led to an aviation system that exhibits a high level of safety that is generally accepted by the public and aircraft safety performance that displays high reliability. The introduction of the unknown (in the form of UAS) into an established system designed specifically for conventional aviation, has the potential to upset a hard-won and delicate balance. This caution impacts the current status of UAS operations, discussed in the next section.

313 Ibid.
314 See Kaiser, ‘UAVs and Their Integration’, above n 46, 163.
315 Huang, above n 249, 14, 15.
318 Kaiser, ‘UAVs and Their Integration’, above n 46, 172.
319 JAA/Eurocontrol Report, above n 59, 17, 19; See generally Clothier and Walker, Casualty Risk Analysis, above n 40; See also De Florio, above n 64, 6 [3.1.1].
D  Current Status of UAS Operations

1  ELOS and the Precautionary Principle

In the absence of a clear way forward, the regulators have adopted a ‘de facto’ requirement that UAS must maintain an ELOS equivalent to the socially acceptable levels of safety currently provided by the existing system. While the term ELOS was originally coined by the JAA in 2004, the intervening years have not brought with them any harmonious understanding of what that term means in practice. Many have tried to ‘divine’ a meaning by resort to statistical means or formula, but these too suffer from a lack of consensus, particularly given that the requirement for safety equivalence does not say or necessarily mean equivalence in regulation nor equivalence in certification procedures. Rather, regulation and certification represent some of the means in the conventional aviation system by which ‘safety’ is said to be obtained. How the same level of safety can be provided for UAS remains an open question. In the absence of an answer to that question, regulators have rightly approached UAS with caution and, as set out above, have applied a ‘precautionary principle’ such that the burden of proof rests on the industry to prove the safety of UAS operations. Enforcing the ELOS requirement is a defensible position for regulators – restrictions will be lifted gradually as experience with UAS operations is gained. In practice, this means that UAS operations (particularly commercial operations) are severely restricted in terms of access to airspace, assessed on a

323 *JAA/Eurocontrol Report*, above n 59, 12, 38, 39.
protracted,\textsuperscript{327} case-by-case basis,\textsuperscript{328} and largely quarantined from interaction with the aviation system. The present interpretation of the ELOS mandate by the regulators therefore provides little positive guidance to the industry.\textsuperscript{329}

2 Market is Seen as Extremely Lucrative but ELOS Creates Uncertainty

This approach is emblematic of a determination by the regulators that safety is of primarily importance and economic considerations, such as fostering growth, are secondary matters.\textsuperscript{330} There is an obvious tension here when it is recalled that the market projections indicate the UAS industry is likely to be worth about $11.5 billion globally by the end of the next decade.\textsuperscript{331} The sentiment in the regulatory scene therefore is a juxtaposition of enthusiasm, confusion, and frustration.\textsuperscript{332} This has a negative effect on the market; commercial imperatives ordinarily require some degree of certainty as to the regulatory landscape before investment decisions can be made:\textsuperscript{333}

Users, manufacturers and others in the UAS community need to know their rights and responsibilities. A limited regulatory framework is the reason for slower development of civil UAS due to higher risks in a less regulated area. Like a circle, increasing applications encourages regulation and legal certainty encourages investment and development.\textsuperscript{334}

\textsuperscript{327} Kaiser, ‘Legal Aspects of UAVs’, above n 83, 351.
\textsuperscript{328} See, eg, \textit{AAIF Report}, above n 11, 6.
\textsuperscript{329} \textit{AAIF Report}, above n 11, 12; Coyne, above n 143, 3.
\textsuperscript{330} There has been considerable study of this issue in the context of air law generally over time; the breadth cannot be covered in this thesis. It is enough to note some examples; Bartsch, for instance, notes that ‘safety’ and ‘growth’ are ‘dual objectives’, \textit{Chicago Convention} art 44: Bartsch, above n 259, 107. The Transport Canada UAV Working Group commented that it will seek to balance mission requirements with public safety to achieve workable solutions, but safety will always have priority: TC, above n 160, 71. CASA has made similar comments: ‘CASA, as Australia’s civil aviation safety regulator, has no authority to allow economic or commercial imperatives to influence safety-related decisions that we are obliged to make. It is only after all relevant safety-related factors have been considered with due precedence, that the economic or commercial considerations of that decision might be taken into account.’

\textsuperscript{331} Teal Group Corporation, above n 122.
\textsuperscript{332} See generally Argrow, Weatherhead and Frew, above n 130.
\textsuperscript{333} Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 167.
\textsuperscript{334} Plucken, above n 46, 8.
However the situation as described above is that the airspace access presently obtainable for UAS through the provisional regulations in force from place to place is normally limited to restricted zones and approved areas by way of special flight permits.\textsuperscript{335} These permits are essentially conditional exemptions to compliance rather than positive authorisations that confer substantive rights on the holder (in the way that a certificate of airworthiness does).\textsuperscript{336} Although testing and restricted zones (such as occurs in, for instance, Australia and the US)\textsuperscript{337} provide some ability for operators to test their products, UAS operators require routine access to the airspace over populated areas because that is where UAS are to undertake their intended missions.\textsuperscript{338} Without the kind of file-and-fly access available to conventional aircraft,\textsuperscript{339} the business cases underpinning most UAS development will be postponed or defeated.\textsuperscript{340} Despite a growing presence in the aviation sector, it is thought that current operational restrictions on UAS operations ‘significantly impede’\textsuperscript{341} the use of UAS for public benefit and are a major obstacle for routine civil UAS operations.\textsuperscript{342}

More critically, without international consensus there is no clear ‘pathway’ to achieving airworthiness certification.\textsuperscript{343} Bearing in mind the ambiguous ELOS requirement by which UAS operators must prove the safety of UAS, there is little guidance as to how to proceed towards obtaining operational freedoms in light of the current restrictions. Traditionally, the issuance of a certificate of airworthiness provides an assurance as to the safety of particular aircraft, and the certification process therefore represents a relatively well-known, and established, gateway to airspace access.\textsuperscript{344} It is therefore likely some form of

\textsuperscript{335} Most of the current UAS regulations in place globally use ‘temporary and ad hoc measures to mitigate the perceived risks [and] lack objective justification’: Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1005.

\textsuperscript{336} See generally Kaiser, ‘Legal Aspects of UAVs’, above n 83, 345.

\textsuperscript{337} Kapnik, above n 127, 448; AIAF Report, above n 11, 18.

\textsuperscript{338} Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1004, 1006; Simpson, Brennan and Stoker, above n 266, 637; Kaiser, ‘UAVs and Their Integration’, above n 46, 166.

\textsuperscript{339} AIAF Report, above n 11, 2; Kaiser, ‘Legal Aspects of UAVs’, above n 83, 354.

\textsuperscript{340} Weibel and Hansman, above n 47, 92; See also AIAF Report, above n 11, 6.


\textsuperscript{342} Plucken, above n 46, 33.


\textsuperscript{344} AIAF Report, above n 11, 6; Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 4; \textit{JAA/Eurocontrol Report}, above n 59, 19. Kaiser notes that airworthiness certification and the freedom of
airworthiness certification process will be needed for UAS in practice (if not a pre-
requisite under the requirements of the Chicago Convention). Therefore, the lack of
regulatory framework enabling regular commercial operations for UAS is a recurring
theme in the current body of authorship in relation to the regulation of UAS, which
persists despite the increasing visibility of UAS operations.

3 Difficulties in Controlling UAS Usage

A survey of UAS industry participants in 2010 found that most participants believed it
would take until approximately 2020 before authorised, routine operations for UAS in
civil airspace would emerge. That being the case, the survey concluded that ‘many
continue to conduct operations and testing in violation of [the rules]’. In some cases,
operators believe they are operating legally, only to find out later that is not the case.
This issue recently and publicly came to the fore in the Pirker case in the US relating to an
attempt by the FAA to fine a small drone operator for ‘reckless operation of an aircraft’
when he crashed a 1kg UAS-AC at the University of Virginia during an aerial robotics
convention. Although the first instance decision in favour of Mr Pirker was overturned
on appeal, this was the first real challenge to the FAA’s authority to regulate small
UAS. The fact the decision was overturned seems to have had little impact on the
number of UAS operations taking place outside the rules. Numerous high profile incidents
have occurred particularly with small UAS: one crashed on the Sydney Harbour Bridge,
another crashed through the roof of a suburban dwelling in Perth, Western Australia,\(^ {353}\) and another landed on the front lawn of the White House (to name a few).\(^ {354}\) It is clear that safety controls are needed urgently; however, small and inexpensive UAS are readily available, profitable for producers, and their operations not easily policed. While ‘larger’ or more complex UAS-AC (for instance, MALE and HALE categories) may be more readily susceptible to regulation in the traditional sense,\(^ {355}\) the pressing question remains with the treatment of ‘small’ or ‘low risk’ UAS and where precisely lines can be drawn between different ‘types’ for the purposes of differing regulatory treatment.\(^ {356}\)

### E Certification and Classification of UAS: Current Approaches

The above analysis shows that despite the dedication of significant resources internationally, the question of regulating UAS has yet to be resolved. However, UAS technologies and design philosophies are so inherently different from those applicable to conventional aircraft that there is no ‘easy fit’, and UAS operations create regulatory issues for each of the three pillars of the existing system.\(^ {357}\) As explained above, each pillar has a role to play in ensuring the safety of the existing system. The certification of aircraft as airworthy plays a particularly important part in providing an assurance of the safety of aircraft operation. This certification process involves an examination by the regulator of the critical components of the aircraft.\(^ {358}\) Once compliance with an established airworthiness category has been confirmed, the aircraft has a degree of operational freedom to undertake commercial operations. The importance of this assurance is crystallised within art 31 of the Chicago Convention, by which the regulators are positively obligated to undertake the airworthiness certification for aircraft.\(^ {359}\)

---


\(^{355}\) See eg Takahashi, above n 21, 510; Peterson, above n 5, 597.


\(^{357}\) AAIF Report, above n 11 7; UAS actually ‘blur’ the lines between the 3 pillars: Maddalon et al, *Perspectives on Unmanned Aircraft*, above n 8, 16.

\(^{358}\) Takahashi, above n 21, 522.

\(^{359}\) The Chicago Convention relates only to international flight, domestic flights utilise similar procedures in practice: See generally Maneschijn et al, above n 42, 346-347; De Florio, above n 64, 6 [3.1.1]. In any event,
The issue of certifying UAS is therefore of primary importance in the regulatory agenda internationally, particularly now that ICAO has clarified that UAS are aircraft and therefore fall within the ambit of the regulators’ responsibility for airworthiness. With this in mind, numerous difficulties arise as to how certification ought to occur. Noting the many differences between conventional aircraft and UAS, including in relation to their intended operations, it is clear that the existing type categories are not necessarily applicable, and that the nature of the risks involved with UAS operations means that airworthiness certification is far more entwined with consideration of the (traditionally discrete) operational and environmental factors. It is equally clear that there can be no ‘one size fits all’ approach to certification given the diversity of UAS discussed above.

Therefore the question of the type categories appropriate for UAS remains open. These issues provide the background to the regulatory task of classifying UAS, with which this thesis is concerned. This section examines the problems of airworthiness certification for UAS that have been identified in the literature. For the purposes of this thesis I have set out 4 of the general issues referred to in the literature in order to expose the conceptual elements of classification that are at play within them.

1 Lack of Airworthiness Certification Basis or Pathway

There is significant uncertainty as to the basis upon which UAS can or should be certificated for the purposes of gaining access to airspace. As set out above, art 8 of the Chicago Convention, which governs airworthiness, requires that all aircraft operating in a State’s airspace must first have been issued with a certificate of airworthiness enabling despite that it may arguably have been the case that the drafters of the Chicago Convention favoured national regulation of UAS over an international regime, the end of goal of harmonisation for UAS design and certification has today assumed a status of significance internationally (as it has for conventional aircraft): see Kaiser, ‘Legal Aspects of UAVs’ above n 83, 355; Plucken, above n 46, 41-44.

360 See Circular 328, above n 5, 2 [1.7], 4 [2.5].

361 Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 14.

362 Plucken, above n 46, 102. For instance, the need for UAS operators to comply with the ‘see and avoid’ requirement (which is typically an issue for the regulation of pilots), and the relationship between operational areas or overflown population densities to the character of the risks involved with UAS, mean that these considerations may form part of airworthiness certification for UAS.

363 See eg Plucken, above n 46, 138; Clothier and Walker, Determination and Evaluation of Safety Objectives, above n 47, 12; Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1005; AIAA, above n 42, iv.

364 See, eg, Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 6, 13; Hayhurst et al, Review of Current and Prospective Factors, above n 214, 6.
such operation. The States have implemented a certification regime for different ‘types’ of aircraft which have been largely harmonised between the States.\textsuperscript{365} Over time the certification regime has developed to encompass a prescriptive code of requirements relating to the design of different ‘types’ of aircraft.\textsuperscript{366}

In the absence of authoritative guidance,\textsuperscript{367} the regulators have adopted the ELOS mandate as set out above.\textsuperscript{368} However, the ELOS requirement provides only an overarching and inherently subjective safety target for UAS and does not provide a certification basis itself,\textsuperscript{369} nor a means of actually satisfying that objective. Nonetheless, it is a regulatory imperative that each of the States determine requirements for the certification of UAS and formulate a viable certification pathway,\textsuperscript{370} whatever the ultimate form of the forthcoming regulations. While the existing rules should not be abandoned outright,\textsuperscript{371} unfortunately it is not possible for UAS to simply comply with the existing certification codes, and there are in any event underlying issues relating to the distinct differences in the airworthiness philosophies applicable to conventional and unmanned aviation.\textsuperscript{372} Therefore, while the ‘default’\textsuperscript{373} approach has been to make ‘adjustments’\textsuperscript{374} to the existing rules because they have created a safe system,\textsuperscript{375} there is no easy way to do this\textsuperscript{376} and the present weight of

\textsuperscript{365} De Florio, above n 64, 48; Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 4. Clothier et al describes type categories of aircraft as comprised of aircraft that are ‘similar in some relevant way’: Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 4. Clothier et al have also stated that ‘[a type category]...is essentially a homogenous grouping of aircraft types and models of generally similar characteristics, based on the proposed or intended use of the aircraft, and their operating limitations’: Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 873.

\textsuperscript{366} See Takahashi, above n 21, 533; Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 5, 6.

\textsuperscript{367} See generally Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 1; Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1004.

\textsuperscript{368} Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1004; \textit{JAA/Eurocontrol Report}, above n 59; Plucken, above n 46, 102.

\textsuperscript{369} Simpson et al note that the ELOS requirement lacks the requisite level of detail: See generally Simpson, Brennan and Stoker, above n 266, 644. Indeed, the word ‘safety’ is itself a subjective concept: Bartsch, above n 259, 547.

\textsuperscript{370} \textit{AAIF Report}, above n 11, 6.

\textsuperscript{371} Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 1 noting the strong desire to leverage the existing framework, and additionally the fact that rule changes of this kind are time consuming.

\textsuperscript{372} De Florio, above n 64, 68; Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 1.

\textsuperscript{373} Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 871.

\textsuperscript{374} See Masutti, above n 100, 7.


\textsuperscript{376} There is no ‘good fit’ with the existing categories: Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 16.
opinion on the point is that UAS require a purpose-built certification regime.\textsuperscript{377} There are generally considered to be two available options:\textsuperscript{378}

(a) Code of Requirements: This approach closely follows the approach adopted for the certification of conventional aircraft; that is, a comprehensive and prescriptive code is developed that provides a list of detailed technical requirements with which UAS of different ‘type categories’ must comply in order to obtain certification. The level of certification would effectively dictate the level of operational freedom.\textsuperscript{379} This approach is therefore familiar to regulators and operators,\textsuperscript{380} however, it will take time to develop a comprehensive code of this kind, as it did with conventional aviation, and it is not clear how risk factors relating to the operational environment of the UAS (which are the primary risk factors) will be incorporated into this regime when conventional aviation codes do not work in this manner.\textsuperscript{381}

(b) Safety Target Approach: This approach proposes to allow UAS to satisfy the ELOS requirement by demonstrating that they can reach a ‘safety target’, which can be achieved by a combination of design requirements and operational restrictions tailored to the specific operation in question. By this means, operational restrictions may be used to combat concerns relating to airworthiness,\textsuperscript{382} which would bypass the need to develop a comprehensive code.\textsuperscript{383} Essentially this is an ‘outcomes based’

\textsuperscript{377} Hayhurst et al concluded in 2006 that UAS represented ‘fundamentally different category of aircraft’ and commented that a new regulatory framework will be required for UAS: Hayhurst et al, \textit{Unmanned Aircraft Hazards}, above n 11, 3,5; Lin et al also found that the ‘weight thresholds and categories used in CPA are inappropriate to UAS’: Lin, Fulton and Horn, above n 324, 11; See also Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 875; Clothier, above n 53, 2; Palmer and Clothier, above n 36, 15; M Christopher Cotting, ‘An Initial Study to Categorize Unmanned Aerial Vehicles for Flying Qualities Evaluation’ (Paper presented at 47th AIAA Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition, Orlando Florida, 5-8 January 2009), 6.


\textsuperscript{379} Plucken, above n 46, 137.

\textsuperscript{380} That is, the ‘paragraph 1309’ within the existing rules sets out the manner in which new technologies are to be assessed where there is no clear fit with existing categories: See generally \textit{JAA/Eurocontrol Report}, above n 59, 17; Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 4; Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 872.

\textsuperscript{381} The conventional certification system does not generally have regard to the application of the aircraft in terms of airworthiness, at least directly. Kaiser notes, for instance that ‘In the context of air law, the purpose of the vehicle, is normally not considered a criterion’: Kaiser, ‘Legal Aspects of UAVs’, above n 83, 345. See also Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 2; Plucken, above n 46, 94, Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 14.

\textsuperscript{382} \textit{AAIF Report}, above n 11, 7; \textit{JAA/Eurocontrol Report}, above n 59, 17.

\textsuperscript{383} \textit{JAA/Eurocontrol Report}, above n 59, 17; Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111, 316.
approach based on a target accident or fatality rate. By enabling operators to establish their case to the regulators, this approach offers a degree of flexibility and tailoring of the rules, and facilitates UAS operations in the short term (it is said). However, such an approach is unlikely to be practical in the long term, particularly where high volumes of UAS operations would need to be approved on a case-by-case basis. The approach also lacks transparency in so far as the precise requirements in place for particular proposals or proponents are not known to the wider industry.

While some segments of the UAS industry (particularly advocates for small UAS operations) have pushed for the use of a safety target approach, and variations have been proposed by FAA, CAA, CASA and EASA, the prevailing view amongst the current approaches surveyed later in Chapter IV suggests that UAS require airworthiness certification by a comprehensive, standards-based ‘code’. However, the debate continues as to the precise content of the requirements. The majority of the work completed internationally has focused on the development of ‘low-level’, specific airworthiness requirements, and not on the ‘overarching’ or ‘high-level’ necessity to first establish the airworthiness regime itself. Such a regime is taken to be a prerequisite for the development of standards and is an issue of critical importance.

---

387 Plucken, above n 46, 136.
388 Ibid.
391 See Chapter IV.D.1 below for an overview of the relevant approaches.
394 AAIF Report, above n 11, 6, 7; Vacek, above n 185, 21; Clothier et al, Definition of Airworthiness Categories, above n 3, 1; Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 873; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 1.
396 Clothier et al, Definition of Airworthiness Categories, above n 3, 884; Michaelides-Mateou and Erotokritou, above n 27, 117.
Ultimately, whether a ‘code’ or ‘safety target’ approach is taken in developing that framework, different types or classes of UAS (or UAS operations) must be defined so that standards and rules can be developed. This is a troubling regulatory (and legal) issue.397

2 Lack of Knowledge regarding Assessment of Risk

Conventional aviation activities present various risks to people and property on board the aircraft, on board other aircraft, and overflown by the aircraft – all of which are risks that have influenced the shape of existing regulations. As outlined above, studies of the ‘risk philosophies’ underpinning existing regulations indicate that the philosophies have changed as aircraft technology has developed and commercial operations have expanded.

There has been a discernible shift in focus from the safety objective of protecting populations overflown primarily, to the protection of passengers and crew.398 This is the foremost consideration in modern airworthiness assurance, sparked by the advent of modern commercial air travel and the significant numbers of people in transit aboard aircraft at any given time of day.399 Therefore, the primary driver in the certification of conventional aircraft is thought to be the minimisation of risks to persons on board the aircraft.400 The thinking is that by minimising the risks to those most affected there is a flow on effect of increased safety for third parties (such as people on the ground) as a by-product.401 Therefore the certification techniques for conventional aircraft have developed without direct reference to the type of operation in question or the environment being overflown, and rather operates according to the use of design codes for different types of

397 See Kaiser, ‘Legal Aspects of UAVs’, above n 83, 345; Kapnik, above n 127, 443.
398 Takahashi, above n 21, above n 21, 516.
399 See generally Huang, above n 249, 15, 16.
a aircraft.\textsuperscript{402} As set out above, adherence to the design codes provides one of the primary bases for the assurance of safety in the modern system.\textsuperscript{403}

However, regulators do not have the benefit of experience when it comes to UAS activities.\textsuperscript{404} The task is complicated by the fact that the risk philosophies underlying existing regulations, which would otherwise provide a readily available benchmark, are inapplicable for the obvious reason that UAS by definition do not carry human occupants.\textsuperscript{405} Put simply, the existing system has always assumed that there was a pilot on board (and therefore at risk by virtue of ‘shared fate’ with the aircraft).\textsuperscript{406} Taking this observation to the extreme, it is possible that one type of UAS could crash hundreds of times and result in the loss of not a single human life.\textsuperscript{407} If that were the case, then although that UAS could hardly be described as ‘airworthy’ in the conventional sense, it may arguably be described as ‘safe’\textsuperscript{408} This incongruous risk philosophy is a major obstacle because the precautionary stance adopted by regulators dictates that UAS proponents must effectively convince the regulator that the technology is safe;\textsuperscript{409} yet the regulators are not equipped with the tools to make an assessment.\textsuperscript{410}

\begin{footnotesize}
\textsuperscript{402} AAIF Report, above n 11, 7, 8; Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1005; Plucken, above n 46, 94; Clothier et al, Definition of Airworthiness Categories, above n 3, 2; Kaiser, ‘Legal Aspects of UAVs’, above n 83, 345. See however the discussion as to the role of ‘motivation for use’ in Hayhurst et al, Considerations of Unmanned Aircraft, above n 49, 14.
\textsuperscript{403} See Lin, Fulton and Horn, above n 324, 1; See generally Takahashi, above n 21.
\textsuperscript{404} There is a lack of knowledge as to the relevant risks. See Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1005; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 1.
\textsuperscript{405} Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1004; Hayhurst et al, Unmanned Aircraft Hazards, above n 11, 1.
\textsuperscript{406} Clothier and Walker, Casualty Risk Analysis, above n 40, 1 quoting McCarley and Wickens, above n 243; See also Plucken, above n 46, 100; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 1; Simpson, Brennan and Stoker, above n 266, 637.
\textsuperscript{407} See Plucken, above n 46, 100; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 1.
\textsuperscript{408} See generally Clothier and Walker, Determination and Evaluation of Safety Objectives, above n 47, 7 [1.5]. This may sound extraordinary, but a large number of UAS are designed to operate in such a way, and many are regarded as expendable (see for instance the comment in Drew et al, above n 18, that at US$5m per system (comprised of 4 included UAS-AC) the Predator is considered by the USAF as being ‘expendable’).
\textsuperscript{409} Maddalon et al, Perspectives on Unmanned Aircraft, above n11, 1.
\textsuperscript{410} AAIF Report, above n 11, 8.
\end{footnotesize}
Many have studied the risks involved with UAS operations, including the AAIF, Clothier et al, Dalamagkidis, Valavanis and Piegl, and NASA. These studies generally indicate that the primary risk to be minimised by the UAS certification regime is the risk to third parties on the ground, and secondarily the risk of mid-air collision. As such, the risks involved are tied to the operating environment (ie – area overflown and airspace used) to a far greater degree than is evident in the existing system. In that regard, the traditionally distinct concepts of ‘airspace’ and ‘aircraft’ regulation are ‘somewhat blurred’ when it comes to UAS. Presently, there is no accepted methodology for ascertaining the ‘risks’ attendant with the operation of UAS. There is no means of readily determining what precisely the risks are, and how these risks are best managed, which hamstrings the development of a certification regime. The corollary is that the regulators do not know when to ‘lift’ the restrictions that are currently in place.

411 AAIF Report above n 11.
412 See, eg, Clothier et al, Definition of Airworthiness Categories, above n 3; Clothier and Walker, Casualty Risk Analysis, above n 40; Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22; Palmer and Clothier, above n 36; Clothier, Airworthiness; Clothier, above n 53; Clothier and Walker, ‘Safety Risk Management’, above n 40.
414 Hayhurst et al, Unmanned Aircraft Hazards, above n 11, Maddalon et al, Perspectives on Unmanned Aircraft, above n 8; Maddalon et al, Considerations of Unmanned Aircraft, above n 49.
416 Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111, 316. Specific consideration of mid-air collision risk is beyond the scope of this paper. JAA/Eurocontrol Report, above n 59 notes that airworthiness requirements do not address the risks of mid-air collision: at 16. The AAIF notes that UAS airworthiness requirements may need to address mid-air collision, noting a division between ‘operational airworthiness’ and ‘technical airworthiness’. This thesis is focused on the latter given risks to persons and property on the ground are arguably the primary risks of UAS operation (see above n 415).
417 AAIF Report, above n 11, 7, Clothier et al, Definition of Airworthiness Categories, above n 3, 2; Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 874; Palmer and Clothier, above n 36, 14. For instance, Clothier et al note that UAS risk regulation is ‘heavily dependent on population density’ and, in other work, Clothier et al note that given the ‘type categories’ utilised for the regulation of conventional aircraft are defined by reference only to aircraft characteristics (such as mass), this approach may need to be reconsidered for UAS. See Palmer and Clothier, above n 36, 14; Clothier et al, Definition of Airworthiness Categories, above n 3, 3.
418 AAIF Report, above n 11, 7.
419 Clothier, Fulton and Walker note that there is no objective methodology for ascertaining risk, and this leads to inconsistent risk management: above n 22, 1004; See also Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 10.
421 Ibid.
It is therefore difficult to know where UAS stand now as regards the ELOS requirement, where they need to be, and whether or when they will get there.\textsuperscript{422} Clothier, in particular, has called for systematic and objective investigation of the UAS risk paradigm as a basis for regulatory development, noting this task to be ‘one of the most significant challenges facing the UAS industry’.\textsuperscript{423} The importance of understanding the risks of UAS is now relatively well recognised in the regulatory literature.\textsuperscript{424} Although there remains significant ambiguity or inconsistency in the notions under study (‘risk’, ‘safety’, ‘hazard’),\textsuperscript{425} there is a growing body of work that seeks to formulate and define risk profiles for UAS. For instance, the CAA and JAA/Eurocontrol work in the early 2000s made inroads into the field with initial studies of the kinetic energy equations for UAS.\textsuperscript{426} This was followed by detailed risk management and system engineering studies of the relevant risk equations by Weibel and Hansman of Massachusetts Institute of Technology in 2004,\textsuperscript{427} as well as Dalamagkidis, Valavanis and Piegl,\textsuperscript{428} Hayhurst/Maddalon et al (at NASA)\textsuperscript{429} and Clothier et al from about 2006.\textsuperscript{430} It is clear that there remain a number of factors that require further research,\textsuperscript{431} including the degree of frangibility, the likely reliability of components, and the ability for UAS (particularly small) to penetrate sheltering and structures. These are areas of ongoing research in technical fields – the consensus being that regulations should reflect appropriate risk study but no consensus on what precisely that means.

\begin{itemize}
\item \textsuperscript{422} See \textit{AAIF Report}, above n 11, 13.
\item \textsuperscript{423} Clothier and Walker, \textit{Casualty Risk Analysis}, above n 40, 1. The AAIF has noted that the current stances adopted by regulators lack ‘objective justification’ and are likely based on ‘historical perspectives’ that, it is suggested, have little application to UAS in light of the many differences between the technologies and operations involved: \textit{AAIF Report}, above n 11, 8.
\item \textsuperscript{424} See generally Clothier and Walker, ‘Safety Risk Management’, above n 40, 5.
\item \textsuperscript{425} See Lin, Fulton and Horn, above n 324, 9.
\item \textsuperscript{426} See Haddon and Whittaker, above n 176; \textit{CAP722}, above n 174; \textit{JAA/Eurocontrol Report}, above n 59, 33.
\item \textsuperscript{427} Weibel and Hansman, above n 47.
\item \textsuperscript{428} Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111; Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50.
\item \textsuperscript{429} Hayhurst et al, \textit{Unmanned Aircraft Hazards}, above n 11; Maddalon et al, \textit{Perspectives on Unmanned Aircraft} above n 8; Hayhurst et al, \textit{Review of Current and Prospective Factors}, above n 214; Maddalon et al, \textit{Considerations of Unmanned Aircraft}, above n 49.
\item \textsuperscript{431} Maddalon et al, \textit{Perspectives on Unmanned Aircraft} above n 8, 15 notes that the identification of the relevant factors for the risk study is not clear cut.
\end{itemize}
3 Lack of Ability to Assess Market Impact

The regulatory uncertainty set out above has had the effect of largely restricting actual use of UAS for commercial work. That apparently has not been reflected in forward-looking market assessments so far, which remain buoyant though often caveating the need for regulatory hurdles to be overcome. However, consistent with recent assessments indicating that the US Department of Defense will not continue to be a ‘bulk user’ of UAS, the need for civilian regulations to provide a prompt outlet may emerge. Nonetheless, without having long-term solutions for regulation in place, or at least clear timeframes for the same, it is difficult to assess the impact of the current restrictions on the market.

As with the regulation of other technologies, overly-stringent UAS regulations, can seriously impede market growth through the imposition of direct costs to manufacturers and operators, as well as by undermining the applications presented by the industry. That is, a low cost UAS ought not be subjected to onerous airworthiness requirements without a justifiable basis for doing so. Given that UAS technology can benefit the public by undertaking existing aircraft applications more economically than competing technologies (such as manned aircraft), or by undertaking unique applications that conventional aircraft cannot, the consequences for both the public and the UAS industry of inappropriate regulation cannot be overstated. With all the talk about the risks involved in UAS operations, some have asked ‘What are the risks of not permitting UAS?’ Thus, it is important to ensure that the UAS certification regime imposes requirements and restrictions only to the degree necessary to maintain safety, to ensure that valid applications are encouraged.

However, to date few studies have attempted to understand and analyse the ‘market’ in a way that is sufficient for undertaking regulatory action. In order to understand the

__________________________

432 UAS Vision, above n 9.
433 Clothier and Walker, Determination and Evaluation of Safety Objectives, above n 47, 1; Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 872; AAIF Report, above n 11, 6
434 See De Florio, above n 64, 6 [3.1.1].
435 Papadales, above n 127, 6.
437 AAIF, above n 11, 11.
civil/commercial market sufficiently to proceed with regulatory initiatives, it will be necessary in my view to determine at both a domestic and international level:

(a) the composition of the UAS industry, in terms of the number and types of manufacturers, operators, and UAS in production or development;

(b) the nature of the applications proposed by the industry, with reference to the number and types of manufacturers, operators, and UAS and the degree of access to the airspace system that is required; and

(c) the projected compliance costs involved with the imposition of different airworthiness and other requirements, with reference to each group of manufacturer, operator, and UAS.

Without this information, regulators have no way to gauge the impact of current restrictions, nor any reliable means of assessing the impact of future rules (for instance, airworthiness requirements) on any particular group of manufacturers or operators. The lack of knowledge in relation to these issues precludes proper compliance with governmental rule-making processes, such as the preparation of regulatory impact statements (‘RIS’) (discussed in Chapter VII below) and similar procedures, which are mandatory in most of the Western world. These processes specifically require rule-makers to analyse the costs, benefits and impacts of the new rules to those exposed to them.

However, given the state of UAS regulations globally, few regulators have reached this point in the process. The few RIS that are available, for instance, as produced by CASA (‘CASA RIS’) and EASA, were prepared in the early- to mid-2000s and with respect to the regulators, do not provide a sufficient basis for long-term decision-making. The most recent analysis is incorporated within the FAA NPRM released in 2015. Although more comprehensive, it is apparent that the FAA continues to deal with inadequate

---

438 Civil Aviation Safety Authority, Unmanned Aircraft and Rockets: Civil Aviation Safety Regulation Part 101, Regulation Impact Statement RIS 0016, 14 March 2001, 2, 3. (‘CASA RIS’).
439 EASA A-NPA, above n 169. See also Chapter II.B.1.
440 FAA NPRM, above n 147. See also Chapter II.B.1.
information, specifically stating it lacked sufficient data in relation to the costs and benefits of the propose rules.\textsuperscript{441}

Critically, few analytical studies have looked into the likely cost implications of airworthiness requirements. One such study, conducted in 2004, concluded that the likely weight of a certifiable unmanned aircraft that could operate in public airspace would be in the order of 450kg, by virtue of required reliability and equipage to be carried (ie – transponder, traffic collision avoidance system).\textsuperscript{442} Similarly, the \textit{CASA RIS} for \textit{CASR Part 101} determined that type certification costs for a UAS would likely be in the region of $25,000 (half that of a similar sized conventional aircraft), and approximately $150 for the issue of a certificate of airworthiness.\textsuperscript{443} These analyses are outdated, abbreviated in their content and inadequate for addressing regulations for UAS today. It is clear that the UAS market is continuing to emerge and that the modern regulatory approach requires a far more rigorous approach to the investigation of the above factors if effective and efficient regulation is to be generated.

4 \textit{Lack of International Harmonisation}

There is an underlying imperative to ensure that these problems are addressed in a manner that facilitates international harmonisation, adding a layer of complexity to the task. The imperative derives from the \textit{Chicago Convention}.\textsuperscript{444} This is of more than passing concern given that manufacturers often market their UAS to multiple buyers in multiple countries, and also the fact that aviation in general is an activity that crosses international borders.\textsuperscript{445} Modern UAS are no exception. Even a small, 15kg UAS-AC was able to conduct a flight over the English Channel as long ago as 1998.\textsuperscript{446} This aspect of UAS regulation may be a more immediate concern in Europe where the prospect of international flight is more

\textsuperscript{441} \textit{FAA NPRM}, above n 147, 9547. The \textit{FAA NPRM} specifically invited comments in relation to several issues where the FAA said it ‘lacked sufficient data’. See eg \textit{FAA NPRM}, above n 147, 9547, 9562.

\textsuperscript{442} Casarosa et al, above n 392, 606. Ongoing miniaturisation of the relevant components will likely have reduced that figure (and the cost involved) in the years that have passed. Note however that the \textit{FAA NPRM} states that ongoing miniaturisation has not resulted in the ability of all classes of UAS to carry collision avoidance systems: \textit{FAA NPRM}, above n 147, 9549.

\textsuperscript{443} \textit{CASA RIS}, above n 438, 6.

\textsuperscript{444} Plucken, above n 46, 4; De Florio, above n 64, 6 [3.1.1].

\textsuperscript{445} Giemulla, ‘Chicago System’, above n 59, 4. Huang, above n 249, 229.

\textsuperscript{446} DeGarmo, above n 42, 1-4.
pressing.\(^{447}\) Any domestic UAS certification regime therefore ought to be developed so as to align as much as possible with that of the other States.

A number of efforts are underway internationally with that goal in mind. Unfortunately, UAS regulations have developed haphazardly to date,\(^{448}\) as discussed in Chapter IV below. There is a notable absence of consensus on the fundamental aspects of UAS certification. Compounding the problem is the fact that each regulator will be (quite rightly) motivated to tailor its UAS regulations to ‘…the industry, operational environment, regulatory needs, and the political and social demands of [the] specific nation.’\(^{449}\) Of course these factors will differ from place to place; for instance, Australia has a relatively low population density, a relatively limited capacity for local production, but a potentially substantial requirement for UAS operations such as in the surveillance of its expansive coastal borders. Clothier et al note that harmonisation is the ‘final, practical issue’ for certifying UAS, recognising the potential for ‘incompatibilities’ between domestic and international airspace.\(^{450}\) Although considered in the \textit{FAA NPRM}, the issue was essentially deferred for future consideration in light of the absence of applicable guidance material from ICAO.\(^{451}\)

The need for the harmonisation of UAS regulations has been a noted issue since 1998,\(^{452}\) and more prominent since 2004.\(^{453}\) This has begun to translate into action at national and international (ICAO) level,\(^{454}\) and has been recognised in the existing legal literature.\(^{455}\) Nonetheless, there remains significant disharmony between the current proposals tabled by the regulators.\(^{456}\) Some have noted that the opportunity exists to harmonise UAS

\(^{447}\) See Michaelides-Mateou and Erotokritou, above n 27, 118.
\(^{448}\) The measures put in place by the regulators to date have been in the nature of temporary procedures: Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1005.
\(^{450}\) Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 883; See also Clothier, above n 53, 17.
\(^{451}\) See FAA NPRM, above n 147, 9553, 9554, 9583.
\(^{453}\) See DeGarmo, above n 42, 2-41 - 2-43.
\(^{454}\) See generally Plucken, above n 46, Ch 3, 137, 138.
\(^{455}\) See Kaiser, ‘Legal Aspects of UAVs’, above n 83; Plucken, above n 46, Ch 3.
\(^{456}\) Michaelides-Mateou and Erotokritou, above n 27, 118; Maneschijn et al, above n 42, 352.
regulations at the outset, while the industry continues to form, rather than on an *ad hoc* basis (as occurred for conventional aviation).\textsuperscript{457} This opportunity should be taken.\textsuperscript{458}

The next Chapter explains why classification is central to each of the 4 certification issues outlined above, and how a resolution to classification can facilitate regulatory progress.

\textsuperscript{457} Kaiser, ‘Legal Aspects of UAVs’, above n 83, 355; Plucken, above n 46, 6.
\textsuperscript{458} See Plucken, above n 46, 6, 137, 138; Kaiser, ‘Legal Aspects of UAVs’, above n 83, 355.
IV Classification as a Logical Starting Point in Certification

DeGarmo observed in 2004 that there was a clear need, even at that time, for definition and clarity in relation to several fundamental issues concerning UAS before progress could be made in relation to standards development. He said

a primary challenge for the UAV community will be to coordinate the standards activities so that they complement rather than duplicate or contradict one another. But a first step needs to be made on reaching agreement on definitions, terms, and classifications as they relate to UAVs. In the absence of such agreement, the job of developing consensus standards that are nationally and internationally recognized and adopted will be made more difficult.459

These issues of definition, terminology and classification were canvassed in Chapter II. The difficulties in interfacing between the UAS domain and the existing safety system were raised in Chapter III. This Chapter IV focuses squarely on the topic of classification, which has been flagged in the foregoing Chapters but not yet analysed in detail. The following provides an overview of classification as a general concept, identifies the close linkage between classification and the certification of UAS, and reviews the approaches to UAS classification taken so far. This provides a launch pad for an assessment of the current approaches in Chapter V.

A The Nature of Classification

Issues of classification are not unique to UAS regulation. Rather classifications occur in numerous disciplines, and classification – in and of itself – has emerged as a field of study.460 Classifications occur and are studied across disciplines, organisations, and societies for different purposes and with different degrees of formality. They are endemic in human life and innate in human reasoning.461 As such, classification is not an issue exclusive to UAS by any means: whenever differences are discerned between one thing and another, a classification scheme of some kind is created or maintained. At a basic

459 DeGarmo, above n 42, 2-42.
460 Sokal notes for instance that there is a ‘body of general classificatory theory and methodology [that] is rapidly being developed, a task that is attracting the interest of statisticians and mathematicians.’: Sokal, above n 43, 1115.
level, a classification is a set of definitions which describe phenomena in terms of the characteristics attributed to, and which define, different ‘types’ of things.\footnote{NASA’s work cites a dictionary definition of classification, and also discusses the use of the words ‘class’ and ‘category’ in conventional aviation regulations. See Maddalon et al, \textit{Perspectives on Unmanned Aircraft} above n 8, 3.}

It is necessary to ask: What is classification, exactly? There may be thought to be 3 different types of classifications, which I will refer back to in several aspects of this thesis: first, ‘folk or everyday’ classifications, such as those used to navigate the aisles of a supermarket and the various categories of goods; secondly, classifications may be of a ‘scientific’ variety, such as in the studies of the plant and animal kingdoms, where classifications have been used for centuries to understand and catalogue the natural world. Finally, classifications may be ‘official’ when they are encoded in a society’s laws.\footnote{This is derived from the work of Starr, above n 55. See Chapter V below.} All forms of classifications have similarities, though they utilise different approaches and for different purposes. The types are also interrelated; for instance official classifications may ‘influence every day understanding and even scientific thought’.\footnote{Starr defines official categories as ‘the categories officially adopted or approved by the state and incorporated into law and administration’: Starr, above n 55, 263.}

A textbook on the concept of ‘Classification’ from a statistical perspective provides a useful starting point: classification ‘is a process that involves an investigation of the relationships between a set of ‘objects’ in order to establish whether or not the data can be validly summarised by a small number of classes… of similar objects’.\footnote{Starr, above n 55, 264.} From a scientific perspective, classification is ‘the ordering or arrangement of objects into groups or sets on the basis of their relationships’.\footnote{A D Gordon, \textit{Classification} (Chapman & Hall/CRC, 2nd ed, 1999), 1.} From a criminological perspective, classification can be defined as ‘the allocation of persons to classes in such a way that persons in each class are similar. Or, in a more formal, statistical sense, classification has occurred whenever people are grouped in such a way that the variance within groups is less than the total variance’.\footnote{Sokal, above n 43, 1116.} Finally, the comments of former US Chief Justice Taft in
Truax v Corrigan, 257 US 312, (Ariz, 1921), 337-338 (extracted in Chapter II above) provides an example of the legal perspective, emphasising the need for classification to observe real distinctions and similarities as defined by the relevant legal purpose.

The term can also be used to denote different phases of study: classification can be a ‘process’ or ‘investigation’; it can also refer to the results (or the ‘end product’)469 of that process – a ‘classification scheme’ or ‘classificatory system’.470 There is also a third meaning, which denotes the use of a classification scheme to identify or assign objects to a defined class once the classification scheme has been formed.471

Important themes can be identified. First, on one view classification is a process; an investigation into whether a group of objects can be arranged into smaller groups based on perceived similarities in a way that is valid.472 Simultaneously, a classification (as a scheme) can also be the result of such an investigation. Further, classification refers to the use of the scheme in practice (sometimes also called ‘assignment’ or ‘identification’).473

Therefore, classification processes serve as important tools for analysing, communicating and arranging ideas or concepts. Therefore, the topic of classifying UAS is one that incorporates the analysis of UAS data and characteristics, the creation of a classification scheme, and the use of the scheme. This reflects the fact that classification schemes are not ‘fixed’ entities; rather, they can change and evolve over time as the underlying circumstances change and issues in using classification schemes becomes apparent. Classification schemes should therefore be continually subjected to scrutiny to determine whether they do, and continue to, fulfil their purposes.

Secondly, classification involves a need to make determinations as to the similarities between objects and groups of objects. This calls into question the nature of the relationships between the objects and the need to determine the characteristics of the

al, Definition of Airworthiness Categories, above n 3, 4. This too aligns with the comments of Chief Justice Taft in Truax v Corrigan, 257 US 312, (Ariz, 1921), 337-338.

469 Sokal, above n 43, 1116.


471 Sokal, above n 43; Brennan Brennan, above n 470, 202.

472 This understanding of classification is present in some of the technical work relating to UAS. See, eg, Clothier et al, Definition of Airworthiness Categories, above n 3, 4.

473 Sokal, above n 43, 1116; Brennan Brennan, above n 470, 202.
objects that are relevant to the task at hand. Essentially, whether conducting or analysing a classification, one is confronted with questions as to whether the objects within a group (or proposed group) are ‘truly’ similar, and whether objects within different groups, and the groups themselves, are distinctly different and dissimilar. These issues can be observed in the comments of former Chief Justice Taft in the quote extracted above; the concern is to ensure the validity of the classification.

Finally, all of these related questions of validity, similarity, difference, and relevance imply the existence of a guiding purpose or purposes with regard to which such questions must be resolved. Somewhat surprisingly, these important concepts have not yet been examined directly or in real detail in the context of UAS classification. Bearing in mind that the need for ‘careful thought prior to conducting a classification study has been emphasised repeatedly’, this study of UAS classification and its role in airworthiness certification proceeds in a more linear fashion, from diagnosis to prognosis. The goal is to study UAS classification in detail, set in its context amongst the certification debate.

B Issues of Classification are Inherent in the Certification Challenges

Despite the relative lack of study of the classification question specifically, there are natural starting points in approaching the certification of UAS. To begin with, a century of experience in the regulation of conventional aircraft ought not be discarded summarily. To that end it seems that UAS regulations will resemble the existing regulations in some way: ‘drones are not so revolutionary as to warrant disregard for [the] tried and true system of aviation law’. Therefore, although the precise content of the regulatory approach to UAS remains to be seen, it can be reasonably expected that any UAS certification regime will in some way resemble the approach taken to conventional

---

474 See generally Sokal, above n 43, 1116. In the context of UAS classification, Clothier and Palmer note that: ‘the choice of attribute depends on the regulatory context in which the classification scheme is to be used’: See Palmer and Clothier, above n 36, 2.
475 Of the work surveyed for the purposes of this thesis, the most developed consideration of classification as a concept can be found in the work of AAIF, Clothier et al, NASA, and Fraser and Donnithorne-Tait. This work is analysed in Chapter IV.D of this thesis.
476 Brennan, above n 470, 232; See also Gordon, above n 466, 6.
477 Maddalon et al, Perspectives on Unmanned Aircraft, above n 11, 2.
478 Takahashi, above n 21, 533.
As a matter of practice the approach to the creation of a certification regime ought to involve (in a manner that intersects each of the 4 challenges noted in Chapter II.E):

(a) the development of safety standards or criteria for the airworthiness assessment of UAS;

(b) differing safety standards for different UAS or different UAS operations, including some category or categories of UAS that are exempt from compliance with airworthiness requirements, and

(c) differing airspace access depending on the level of airworthiness or possibly the degree of risk involved with a given UAS or UAS operation; and

(d) the need to nonetheless harmonise the approach to UAS certification internationally, notwithstanding differences in local conditions.

Bearing in mind the definitions of classification discussed above, it is clear that each of these assumptions involve the differentiation of some UAS from others, whether this is a question of the application of differing safety standards, the allocation of differing airspace access for different risk levels, or ensuring that the treatment of UAS of differing types is relatively consistent from place to place. Thus, it is apparent that classification issues occur within each of the certification issues set out in Chapter II.E. Therefore, the development of an appropriate classification scheme for UAS represents a natural starting point for developing regulations – this is consistent with DeGarmo’s observations on that very point (which serve as the introductory words to this Chapter) in 2004.

There is a force of logic to DeGarmo’s observations: it is difficult to see how progress can be made

---

479 See generally Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 4 - 6.
480 See generally *Yearbook 2014*, above n 167, 11 (Per EASA); Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 6.
481 Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 5.
485 See Maddalon et al, *Perspectives on Unmanned Aircraft*, above n 8, 6, 19.
internationally without first consolidating the key terms of reference provided by the development of a classification scheme.

C  Difficulty in Addressing Regulation without Classification

The certification regime for conventional aircraft utilises a classification scheme in order to give effect to the requirements of the Chicago Convention that each nation must issue airworthiness certificates having regard to the technical specifications contained in annex 8 of the Convention.\(^{486}\) Type categories have arisen out of necessity based on the specifics of the aircraft in question, particularly the weight or mass of the aircraft as this is seen to be a *de facto* measure of the likely number of passengers on board,\(^ {487}\) and therefore a measure of the likely risks involved in the flight.\(^ {488}\) In that regard, the existing system establishes weight thresholds such as \(< 600\text{kg and 5670kg}\) and specifies that such aircraft are to comply with Ultralight (\(< 600\text{kg}\)), Part 23 (\(< 5760\text{kg}\)) and Part 25 (\(> 5760\text{kg}\)) of the airworthiness codes respectively.\(^ {489}\) As set out in Chapter III above, conventional aircraft are therefore grouped into relatively homogenous groups,\(^ {490}\) and the requirements for certification are known ahead of time for those seeking to design, sell and use such aircraft.\(^ {491}\) In this way, a classification scheme has been created that defines a small number of groups of similar aircraft from the variety of aircraft available on the market, such that these groups of aircraft can then be dealt with in similar ways.\(^ {492}\) The certification regime itself – not just the detailed standards – has developed over time as technology has evolved and lessons have been learned.\(^ {493}\)

\(^{486}\) See De Florio, above n 64, 6 [3.1.1]; Maneschijn et al, above n 42, 346.
\(^{487}\) See above n 70 above in relation to the use of the term ‘mass’.
\(^{489}\) Weibel and Hansman, above n 47, 36 n 1; See Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111, 316, 317.
\(^{490}\) De Florio, above n 64, 48; Clothier et al, *Definition of Airworthiness Categories*, above n 3,4; Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 873.
\(^{491}\) Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 4.
\(^{492}\) Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 5; Maddalon et al, *Considerations of Unmanned Aircraft*, above n 49, 3.
\(^{493}\) See Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 6.
The diversity of UAS bespeaks the practical necessity to develop a similar classification for UAS. The reality is that regulators will be faced with an increasing number of applications from UAS operators and manufacturers seeking to use their UAS in civil airspace. As has been borne out by experience with conventional aircraft, there is a need to afford regulatory treatment to UAS in groups (rather than on an individualised basis). On the one hand, it is readily accepted that there is no ‘one size fits all’ solution for UAS regulations; on the other, the sheer number of UAS and their extraordinary variety would result in an unacceptable burden on regulatory resources if UAS operations were to be assessed on a case by case basis going forward. On the understanding that UAS are aircraft as directed by ICAO, and that art 31 of the Chicago Convention applies to UAS generally, then the motivation exists for pursuing a certification regime similar in scope to that which has developed for conventional aircraft. The classification of UAS into smaller, manageable groups of similar aircraft is therefore a vital regulatory tool, and a logical first step in developing standards and regulations. In the context of the modern approach to regulation requiring the development of consensus standards where possible, the concept of a classification scheme for UAS should therefore be seen an issue fundamental to stakeholder communication and the progress of regulations.

D Current Approaches to Classification

It is telling that each of the regulatory initiatives mentioned in Chapter II contains some form of classification scheme. This section focuses specifically on the classification aspects of the existing regulatory work in order to examine how classification is

494 Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 5.
495 See, eg, Plucken, above n 46, 138; Clothier and Walker, Determination and Evaluation of Safety Objectives, above n 47, 12; Palmer and Clothier, above n 36, 229; Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1005; AIAA, above n 42, iv.
496 Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 5; Yearbook 2014, above n 167, 108 (per Unmanned Systems Canada).
497 Circular 328, above n 5, 2 [1.7], 4 [2.5].
498 See Plucken, above n 46, 104, noting that although Chicago Convention art 31 may apply, Chicago Convention annex 8 does not cover ‘aerial work’ (which UAS are expected to undertake) nor to fixed-wing aircraft below 750kg.
499 DeGarmo, above n 42, 2-40 – 2-42, 3-1, 3-2; Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 5, 6; AIAA, above n 42, iv. See generally Palmer and Clothier, above n 36; Clothier et al, ‘Airworthiness Certification Framework’, above n 49.
500 The need for clarity in communication between the regulators and UAS stakeholders is noted by Vacek: Vacek, above n 185, 22.
addressed. This examination is useful as a precursor to discussion later in this thesis as to how UAS classifications can be analysed with greater precision by reference to the relevant legal dimensions. The following approaches have been selected for review on the basis that they represent influential work in the regulatory domain;\textsuperscript{501} in that regard, a sample of both the recent work as well as the seminal, historical work is included in order to illustrate the course of developments over time.

1  Regulatory & Standards Setting Approaches to the Classification of UAS

\textit{Australia (CASA)}

A case study of the \textit{CASR Part 101} classification scheme is undertaken in Chapter VIII of this thesis. As such, the classification scheme is dealt with in this section in a preliminary fashion only.

The \textit{CASR Part 101} regulations include a classification scheme which groups UAS according to the MTOW of the UAS-AC. \textit{CASR Part 101} has force as delegated legislation pursuant to the \textit{Civil Aviation Act 1988 (Cth)} (‘Aviation Act’). As such, the classification scheme uses definitions within \textit{CASR Part 101} that partition the broader group of UAS into 3 weight classes, to which operating rules and restrictions are attached (inter alia). UAS are also partitioned according to configuration, ie – fixed wing, rotary wing, airship or powered parachute.

The scheme can be set out as follows:\textsuperscript{502}

<table>
<thead>
<tr>
<th>UAS Class</th>
<th>Micro UAV</th>
<th>Small UAV</th>
<th>Large UAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airship</td>
<td>N/A</td>
<td>&lt; 170m$^3$ (envelope)</td>
<td>&gt; 170m$^3$ (envelope)</td>
</tr>
<tr>
<td>Powered Parachute</td>
<td>N/A</td>
<td>&lt; 150 kg</td>
<td>≥ 150kg</td>
</tr>
<tr>
<td>Aeroplane</td>
<td>&lt; 100g</td>
<td>≥ 100g &lt; 150kg</td>
<td>≥ 150kg</td>
</tr>
</tbody>
</table>

\textsuperscript{501} Note that ICAO’s consideration is not set out below on the basis that it has not as yet put forth a proposal for classification, though it has noted the topic to have potential utility to risk management, with work underway at ICAO level: \textit{RPAS Manual}, above n 54, 2-3 at [2.2.7]. NASA has also undertaken a comprehensive review of the current approaches to classification. See Maddalon et al, \textit{Perspectives on Unmanned Aircraft} above n 8.

\textsuperscript{502} Note that Maddalon et al, \textit{Perspectives on Unmanned Aircraft} above n 8 sets out a table in similar terms: at 27.
There is little information available concerning precisely how these groups were generated by CASA. It appears that CASA itself had limited available information on UAS at the time and that the classification scheme was designed by CASA without undertaking a comprehensive risk assessment.503

CASA has recently proposed amendments to CASR Part 101 by way of a proposed Part 102 that takes account of advances in understanding and measurement of UAS risks, in particular studies of kinetic energy and harm potential for various UAS.504 The new rules propose a fourth weight class of UAS for those UAS-AC with a mass between 250g and 2kg, on the basis that risk studies indicate such aircraft would cause minimal harm.505

Canada (Transport Canada)

TC regulates UAS by requiring that no UAS may operate unless issued with a Special Flight Operations Certificate (‘SFOC’) pursuant to the Canadian Aviation Regulations.506 TC commissioned a report on UAS in 2006 via its UAV Working Group which proposed several weight classes for UAS based on existing weight limits sourced from existing

---

503 Civil Aviation Safety Authority, Notice of Proposed Rule Making - Remotely Piloted Aircraft Systems, NPRM 1309OS, May 2014, 8 (‘CASA NPRM 2014’); Another source notes that the classification was developed on a ‘risk management approach’: see Malcolm M J M Walker, ‘Airworthiness Standards for Australian UAVs’ (Discussion Paper, Civil Aviation Safety Authority–Australia, 29 May 2000) 1. Note that this paper is no longer available online; however, see Clothier and Walker, Casualty Risk Analysis, above n 40, 2 which also cites the document and confirms the statement. See Chapter VIII for further details of the CASR Part 101 classification scheme.

504 See CASA NPRM 2014, above n 503, 2, 8.

505 CASA NPRM 2014, above n 503, 8.

506 Canadian Aviation Regulations regs 602.41 and 603.66.
Canadian Aviation Regulations for model aircraft (35kg) and the EASA delimitation for UAS (150kg).\textsuperscript{507} Although these weight classes were not formalised, several exemptions to the SFOC requirement have been authorised by TC. This results in a classification scheme based firstly on whether the UAS is used for work and research, secondly on the weight of the UAS-AC, and thirdly on whether the operator can meet the exemption requirements. The following classification scheme can be constructed from TC’s guidance material:\textsuperscript{508}

<table>
<thead>
<tr>
<th>UAS Class</th>
<th>Weight</th>
<th>Exemption</th>
<th>Applicable Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Use</td>
<td>0 to 2kg</td>
<td>Meets exemption eligibility</td>
<td>No TC Permission required</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Doesn’t meet exemption eligibility</td>
<td>Must have SFOC</td>
</tr>
<tr>
<td></td>
<td>2.1 to 25kg</td>
<td>Meets exemption eligibility</td>
<td>No TC Permission required but must contact TC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Doesn’t meet exemption eligibility</td>
<td>Must have SFOC</td>
</tr>
<tr>
<td>Private Use\textsuperscript{509}</td>
<td>0 to 35kg</td>
<td>Meets exemption</td>
<td>No TC Permission</td>
</tr>
<tr>
<td></td>
<td>35kg +</td>
<td>Doesn’t meet exemption</td>
<td>Must have SFOC</td>
</tr>
</tbody>
</table>

\textit{Table 5: Transport Canada Classification Scheme}

Again, there is little information available as to the specific basis upon which this classification scheme has been generated, save that the 25kg and 35kg limits have been based upon model aircraft limitations,\textsuperscript{510} in respect of which Canadian Aviation Regulations specify the latter as the relevant weight,\textsuperscript{511} though for most of the other jurisdictions discussed in this thesis, the limit is 25kg. Fraser and Donnithorne-Tait note that the 35kg demarcation likely arose in an arbitrary fashion based on a survey of model aircraft undertaken at the time the regulations were drafted.\textsuperscript{512}

\textsuperscript{507} See generally Maddalon et al, \textit{Perspectives on Unmanned Aircraft} above n 8, 26.
\textsuperscript{508} Office of Civil Aviation Standards (Canada), above n 164; See Transport Canada, above n 165.
\textsuperscript{509} This thesis is only concerned with the use of UAS for commercial purpose – the private use classification is included here by way of comparison to show the differing weight limits used for private as opposed to commercial purposes.
\textsuperscript{510} Office of Civil Aviation Standards (Canada), above n 164, p3.
\textsuperscript{511} Office of Civil Aviation Standards (Canada), above n 164, p3.
\textsuperscript{512} Fraser and Donnithorne-Tait, above n 211, 162.
**United Kingdom (CAA)**

The CAA classification scheme under *CAP722* has undergone numerous changes over the years as the document has been continually updated. The scheme utilised under *CAP722* presently is set out as follows:\(^{513}\)

<table>
<thead>
<tr>
<th>Mass Category</th>
<th>Mass (kg)</th>
<th>Responsible Regulatory Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUA</td>
<td>0 to 20</td>
<td>National Aviation Authority</td>
</tr>
<tr>
<td>Light UAS</td>
<td>&gt;20 to 150</td>
<td>National Aviation Authority</td>
</tr>
<tr>
<td>Not Defined</td>
<td>Above 24kg</td>
<td>EASA</td>
</tr>
</tbody>
</table>

*Table 6: CAP722 Classification Scheme*

The classification under *CAP722* is actually an amalgamation of sources, bearing in mind that the upper limit of its coverage is 150kg as dictated by EASA regulations (with some exceptions for certain kinds of UAS, for instance, research aircraft), EASA has responsibility for safety oversight.\(^{514}\) Additionally, the *Air Navigation Order 2009* (UK) creates a definition for UAS-AC weighing less than 20kg as being a ‘small unmanned aircraft’; such aircraft are exempted from the requirement to obtain airworthiness certification and subjected instead to operational restrictions, including that no aerial work may be undertaken without permission.\(^{515}\) Though not depicted above, the *Air Navigation Order 2009* (UK) also establishes further operational categories based on whether the UAS-AC weighs more or less than 7kg and whether it is equipped with surveillance devices.\(^{516}\) For UAS-AC above 20kg, airworthiness certification is required to be obtained unless exempted by the CAA; in practice this is to be governed by safety case process rather than formal airworthiness certification procedures.\(^{517}\) It must be said that these are

---

\(^{513}\) Note that Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8 sets out the scheme in a similar terms. See Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 29.

\(^{514}\) See *CAP722*, above n 174, 23-24. See also Michaelidis-Mateou, above n 27, 117.

\(^{515}\) Ibid 25 [2.18], [2.19], 37-38 [3.19]-[3.20]; See *Air Navigation Order 2009* (UK) SI 2009/3015, O255(1), 166 (note the definition of “Small unmanned aircraft” in O255(1)).

\(^{516}\) *CAP722*, above n 174, 37 [3.19].

\(^{517}\) Ibid, 90 25 [2.19].
complex arrangement that are difficult to set out in a single, tabular classification scheme.\textsuperscript{518}

\textit{United States}

\textit{FAA}

US regulations are in a state of flux as the FAA seeks to transition into the arrangements mandated by the \textit{FMRA}. There are currently no positive regulations in force, the FAA presently addressing UAS on a case by case basis through the issuing of exemptions, dependent on whether a public or private UAS is being proposed for use, with exemptions also being issued by the FAA for specific purposes. However, the \textit{FMRA} itself creates a classification of UAS, which the FAA must adhere to in its proposed regulations. Some insights into the US approach to classification can be obtained from a review of the recently released \textit{FAA NPRM} relating to small UAS, in which the following classification can be discerned for civil UAS:

<table>
<thead>
<tr>
<th>UAS Class</th>
<th>Mass (kg)</th>
<th>Applicable Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro UAS</td>
<td>0 to 2kg</td>
<td>Comply with Proposed Part 107 – Able to operate above people</td>
</tr>
<tr>
<td>Small UAS</td>
<td>2 to 24kg</td>
<td>Comply with Proposed Part 107 – Not able to operate above people</td>
</tr>
<tr>
<td>Not Defined</td>
<td>Above 24kg</td>
<td>No Rules Defined</td>
</tr>
</tbody>
</table>

\textit{Table 7: FAA NPRM Classification Scheme}

The \textit{FMRA} defines the weight limit for ‘small UAS’ (24kg), and this can be assumed to be a weight defined by reference to the model aircraft rules.\textsuperscript{519} It is also notable that although the 2kg boundary is specified in the \textit{FMRA} by reference to a requirement on the FAA to develop certain rules in relation to public UAS, there is in fact no ‘micro UAS’ class specified in the \textit{FMRA} for civil UAS (and therefore no such class is mandated by the \textit{FMRA}). Rather, the ‘micro UAS’ class is explained in the \textit{FAA NPRM} to have been proposed on the basis of the findings of the sUAS ARC which made its report to the FAA.

\textsuperscript{518} See the extended scheme (taking account of operational/application issues) in Maddalon et al, \textit{Perspectives on Unmanned Aircraft} above n 8, 29.

\textsuperscript{519} See \textit{FMRA} § 331(4).
in 2009 (‘sUAS ARC Report’).\textsuperscript{520} Both the FAA NPRM and the sUAS ARC Report foreshadow the application of operational constraints and the need for frangible construction of a ‘micro UAS’;\textsuperscript{521} as such it appears some kind of risk study has been or will be undertaken in the proposal of weight limits. However, neither document actually explains how the weight limits have been derived.

The FAA itself notes that in developing the FAA NPRM, it considered subdividing the ‘small UAS’ category (those UAS-AC < 24kg) into 5 further subgroups based on ‘weight, operational characteristics, and operating environment’.\textsuperscript{522} The sUAS-ARC Report separately proposed the following classification scheme for UAS under 25kg:\textsuperscript{523}

<table>
<thead>
<tr>
<th>UAS Group</th>
<th>Mass</th>
<th>Operational Limits</th>
<th>Required Operational Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&lt; 4.4 lbs (2 kgs)</td>
<td>Section 9.2</td>
<td>Section 9.3</td>
</tr>
<tr>
<td>II</td>
<td>&lt; 4.4 lbs (2 kgs)</td>
<td>Section 10.2</td>
<td>Section 10.3</td>
</tr>
<tr>
<td>III</td>
<td>&lt; 19.8 lbs (9 kgs)</td>
<td>Section 11.2</td>
<td>Section 11.3</td>
</tr>
<tr>
<td>IV</td>
<td>&lt; 55 lbs (25 kgs)</td>
<td>Section 12.2</td>
<td>Section 12.3</td>
</tr>
<tr>
<td>V</td>
<td>LTA</td>
<td>Section 13 (Reserved)</td>
<td>Section 13 (Reserved)</td>
</tr>
</tbody>
</table>

*Table 8: sUAS ARC Classification Scheme*

It remains to be seen whether these further subclasses will emerge in the FAA’s proposals. Given the FAA has requested comment on whether to adopt that approach, the FAA NPRM represents a work in progress rather than a final position.\textsuperscript{524}

\textsuperscript{520} FAA NPRM, above n 147, 9557.
\textsuperscript{521} FAA NPRM, above n 147, 9557, 9558; Small Unmanned Aircraft System Aviation Rulemaking Committee (US), ‘Comprehensive Set of Recommendations for sUAS Regulatory Development’ (Recommendation Report, Federal Aviation Administration, 1 April 2009) 22, 23 (‘sUAS ARC Report’).
\textsuperscript{522} FAA NPRM, above n 147, 9556.
\textsuperscript{523} Note that NASA presents a similar table: See Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 22.
\textsuperscript{524} FAA NPRM, above n 147, 9556.
AIAA

The AAIA is an industry body comprised of approximately 30 000 members from 88 countries, and established in 1963. During that time it has been involved in the development of standards in the aerospace industry as well as representation as a professional body for its members, largely the engineers and pilots. In 2004 the AIAA published document R-103-2004 entitled ‘Terminology for UAVs and ROAs’, consensus as to which it considered to be the ‘first task’ in the development of standards for such technology. In developing the document, the AIAA considered that:

Because not all unmanned aircraft systems can be treated the same, classes will be defined and standards developed for each class. Classes will be based on a combination of aircraft weight, size and altitude of operation.

What emerged is in effect a dictionary or taxonomy of UAS (referred to as UAVs) and their operations, which gives rise a classification of UAS as follows:

<table>
<thead>
<tr>
<th>UAS Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small airplane</td>
<td>≤ 12,500 pounds (5700kg) max. cert. TOW</td>
</tr>
<tr>
<td>Large airplane</td>
<td>&gt; 12,500 pounds (5700kg) max. cert. TOW</td>
</tr>
<tr>
<td>Medium Altitude Endurance</td>
<td>A vehicle capable of operating at altitudes between 15 000ft and 40 000ft mean sea level for periods greater than 12 hours.</td>
</tr>
<tr>
<td>High Altitude Endurance</td>
<td>A vehicle capable of operating at 40 000ft for greater than 12 hours</td>
</tr>
<tr>
<td>High Altitude Long Endurance</td>
<td>An ROA capable of performing the mission objectives at an altitude of 45 000-foot MSL or higher over a period of at least 24 continuous hours</td>
</tr>
</tbody>
</table>

Table 9: AIAA Classification Scheme

526 AIAA, above n 42, iv. The classification table set out below is compiled from the terminology set out in AIAA, above m 207, iv.
527 AIAA, above n 42, iv.
There is little publicly available information as to the basis upon which these terms have been derived. However, the AIAA classification is useful as insight into early taxonomies developed for UAS, and is illustrative of the ongoing issues experienced in the usage of terms traditionally used for military UAS in the context of civil regulations.

**ASTM**

Having been mandated by the FAA in 2003 to produce ‘practical, consensus standards that facilitate UAS operations at an acceptable level of safety’ ASTM’s F38 Committee established an airworthiness subcommittee charged with developing ‘[m]inimum requirements for UAV system performance and safety for the UAV system classifications established in the regulations.’ The subcommittee’s ‘Standard Terminology for Unmanned Aircraft Systems’, incorporates the following classification scheme:

<table>
<thead>
<tr>
<th>UAS Class</th>
<th>MTOW (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-UAS</td>
<td>≤ 55 (25kg)</td>
</tr>
<tr>
<td>Small-UAS</td>
<td>≤ 330 (150kg)</td>
</tr>
<tr>
<td>Light-UAS</td>
<td>≤ 1320 (600kg)</td>
</tr>
</tbody>
</table>

Table 10: ASTM International Classification Scheme

It was anticipated at the time that design standards applicable to each class would be forthcoming such that Light UAS would be certified under special airworthiness procedures similar to light sport aircraft (LSA, also called Ultralights, or Very Light Aircraft or VLA) and subject to similar restrictions. Large UAS, though not defined under ASTM’s terminology document, were proposed be subject to existing type certification procedures. However, the document was withdrawn by ASTM in 2014

---


531 Ibid.
citing that the standard was no longer relevant to industry (likely because the FMRA significantly and unilaterally altered the regulatory landscape). It is nonetheless included in this review as long-standing industry-derived classification.

Europe

EASA

EASA has proposed a classification of UAS for the purpose of determining airworthiness requirements for UAS under the EASA A-NPA and its subsequent Policy Statement. Rather than use UAS-AC mass as the sole relevant characteristic, EASA proposed two alternatives for determining the applicable CS (Certification Specifications, the EASA equivalent of the FAR types, ie Part 23, 25 etc) to different types of UAS:

(a) Proposal 1 utilised a kinetic energy measure of the UAS-AC to compare UAS characteristics to conventional aircraft. By that means, EASA proposed to gauge similarity to conventional aircraft based on determining which UAS have similar kinetic energy profiles to existing conventional aircraft, and thereby to select the appropriate codes from amongst those existing for conventional aircraft.

(b) Proposal 2 proposed to redefine current weight limits in the EASA regulations to suit UAS based on a safety case methodology taking account of ground impact, kinetic energy, lethal surface area and population density. This safety objective criterion would then be used to correlate with the applicable CS (though few details are provided as to precisely how that would occur).

The first proposal was favoured by EASA. The kinetic energy proposal does not, in fact, define a classification scheme directly (as in the CASA approach for instance).

532 ASTM International, above n 528.
533 See EASA A-NPA, above n 169; Policy Statement, above n 169. See also Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 29.
534 EASA A-NPA, above n 169, 6-7.
535 See ibid 24.
Rather, the scheme arises through kinetic energy ‘applicability regions’ for two impact scenarios (ie an unpremeditated descent, such as an emergency landing of the UAS-AC, and a loss of control scenario) that establish applicable CS. The applicability regions are established according to kinetic energy measurements established for a number of conventional aircraft certified under each CS:\textsuperscript{537}

<table>
<thead>
<tr>
<th>Kinetic Energy Unpremeditated Descent</th>
<th>Applicable Certification Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0001 to 0.001</td>
<td>Microlight</td>
</tr>
<tr>
<td>0.0001 to 0.002</td>
<td>VLA</td>
</tr>
<tr>
<td>0.01 to 0.02</td>
<td>CS23SE &amp; CS27</td>
</tr>
<tr>
<td>0.01 to 0.1</td>
<td>CS23 Twin &amp; CS29</td>
</tr>
<tr>
<td>0.06 to 100</td>
<td>CS25</td>
</tr>
</tbody>
</table>

*Table 11: EASA A-NPA Proposal 1 Kinetic Energy Tables (Unpremeditated Descent)*

<table>
<thead>
<tr>
<th>Kinetic Energy Loss of Control</th>
<th>Applicable Certification Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0015 to 0.01</td>
<td>Microlight</td>
</tr>
<tr>
<td>0.0015 to 0.025</td>
<td>VLA</td>
</tr>
<tr>
<td>0.01 to 0.125</td>
<td>CS23SE &amp; CS27</td>
</tr>
<tr>
<td>0.1 to 2</td>
<td>CS23 Twin &amp; CS29</td>
</tr>
<tr>
<td>0.4 to 1000</td>
<td>CS25</td>
</tr>
</tbody>
</table>

*Table 12: EASA A-NPA Proposal 1 Kinetic Energy Tables (Loss of Control)*

There are few details as to how precisely these groups were developed. It appears that EASA obtained a sample set of conventional aircraft and a sample set of UAS-AC, and then plotted the kinetic energy measurements for each set of aircraft under both kinetic energy scenarios. From there, groups of similar aircraft and UAS-AC appear to have been plotted visually, by drawing a ‘box’ around what appeared (to the eye) to be clusters of aircraft.\textsuperscript{538} By overlaying the UAS-AC clusters on the conventional aircraft clusters, similarity of kinetic energy is then gauged.

\textsuperscript{537} Note that Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 30 set out a table that is similar in its terms to the above; however the numbers translated from EASA’s graphical illustrations are not identical. See *EASA A-NPA*, above n 169, 35, 36 in relation to the tables set out above.

\textsuperscript{538} See *EASA A-NPA*, above n 169, 35, 36; Note that EASA does not actually explain how the clusters were observed. Maddalon et al, *Perspectives on Unmanned Aircraft*, above n 8, notes the classification was developed using ‘visual interpretation’: at 30.
It is worth mentioning the second proposal, though it was not pursued at the time. As an application of the ‘safety target’ methodology described in Chapter III above, there are numerous factors to consider in the construction of the classification scheme. Essentially, the second method proposes a 5-step system to calculate risk profiles for the fleet of conventional aircraft and example UAS-AC in order to measure ascertain which CS are most appropriate according to the risk metrics. The resulting table shows how this might occur for example UAS: 539

<table>
<thead>
<tr>
<th>UAV Type</th>
<th>Mass (kg)</th>
<th>Sref m²</th>
<th>UAV Crash Probability Objective</th>
<th>Equivalent CS-23 Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCAV</td>
<td>25 000</td>
<td>63</td>
<td>8,E-06</td>
<td>Commuters</td>
</tr>
<tr>
<td>HALE</td>
<td>20 000</td>
<td>100</td>
<td>1,E-05</td>
<td>M&gt;6000lb Reciprocating</td>
</tr>
<tr>
<td>HALE</td>
<td>8600</td>
<td>43</td>
<td>3,E-05</td>
<td>M&lt;6000lb Turbine</td>
</tr>
<tr>
<td>MALE</td>
<td>5700</td>
<td>57</td>
<td>5,E-05</td>
<td>M&lt;6000lb Reciprocating</td>
</tr>
</tbody>
</table>

Table 13: EASA A-NPA Proposal 2 Risk Metric Classification

Ultimately, EASA has adopted its ConOps Proposal that is different to both approaches (as set out above), but retains aspects of each. EASA’s ConOps Proposal defines 3 categories of UAS: 540

<table>
<thead>
<tr>
<th>UAS Group</th>
<th>General Description</th>
<th>Operational Limitations</th>
<th>Certification / Approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Category</td>
<td>Very low risk drone operations</td>
<td>Direct Visual Line of Site: 500m at an altitude beneath 150m and away from specified areas (airports etc)</td>
<td>No certification or approval</td>
</tr>
</tbody>
</table>

539 See EASA A-NPA, above n 169, 37. The term ‘Sref m²’ refers to the ‘Lethal Area’ of the UAS-AC based on the calculation methodology set out in the A-NPA. The ‘UAV Crash Probability Objective’ is the result of the risk metric equation (ie – a rough approximation of the number of fatalities per flight hour in the event of a crash). The final column results from a comparison of conventional aircraft exhibiting similar statistics and the Certification Specification used by that aircraft, which is then proposed as the equivalent specification for the UAS. These terms are explained in EASA A-NPA, above n 169, 37.

540 ConOps Proposal, above n 171.
<table>
<thead>
<tr>
<th>Specific Operation Category</th>
<th>Higher risk drone operations</th>
<th>Determined via safety case/risk assessment process</th>
<th>Determined via safety case/risk assessment process (possible industry airworthiness standards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certified Category</td>
<td>Risks akin to conventional aviation</td>
<td>Determined by Certification Specification achieved</td>
<td>The type and airworthiness certification used for conventional aircraft would apply (subject to necessary modifications)</td>
</tr>
</tbody>
</table>

Table 14: EASA ConOps Proposal Classification Scheme

Thus, even within this approach it is clear that classification is at play; for instance, it is likely that some form of classification will arise within the ‘Specific Operation Category’ over time and out of a practical need to avoid high volumes of individualised assessment.\textsuperscript{541} Though EASA says the need for a ‘Certified Category’ is open to debate because there is currently no defined ‘upper limit’ to the ‘Specified Operation Category’, political and practical restraints on the regulatory system may demand the use of a ‘fully regulated’ system akin to that employed for conventional aircraft (which would likely involve a similar typology of aircraft as has developed within the existing safety system).\textsuperscript{542}

**Eurocontrol/IABG**

As the body responsible for the airspace management of European skies, Eurocontrol requested a study of UAS in 2001 (‘Eurocontrol/IABG Report’).\textsuperscript{543} Noting the fundamental need for a classification of UAS in order to determine the way forward for regulation, the Eurocontrol/IABG Report proposed the following classification based on the mass of the UAS-AC:\textsuperscript{544}

\textsuperscript{541} Ibid 4, 5.
\textsuperscript{542} Ibid 5.
\textsuperscript{543} Eurocontrol/IABG Report, above n 488.
\textsuperscript{544} Ibid 21. Note that the NASA presents a table in similar terms: Maddalon et al, Perspectives on Unmanned Aircraft, above n 11, 37.
<table>
<thead>
<tr>
<th>UAV Class</th>
<th>Max TOW [kg]</th>
<th>Range Category</th>
<th>Typical Radius for Tasks [nmi]</th>
<th>Typical max Altitude [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 0</td>
<td>Below 25</td>
<td>Close Range</td>
<td>Below 10</td>
<td>1000</td>
</tr>
<tr>
<td>Class 1</td>
<td>25 – 500</td>
<td>Short Range</td>
<td>10 – 100</td>
<td>15 000</td>
</tr>
<tr>
<td>Class 2</td>
<td>501 – 2000</td>
<td>Medium Range</td>
<td>101 – 500</td>
<td>30 000</td>
</tr>
<tr>
<td>Class 3</td>
<td>Above 2000</td>
<td>Long Range</td>
<td>Above 500</td>
<td>Above 30 000</td>
</tr>
</tbody>
</table>

Table 15: Eurocontrol/IABG Report Classification Scheme

The *Eurocontrol/IABG Report* explains that the weight classes ‘correlate well with other classifications criteria like range, mission radius and maximum flight altitude’.\(^5^4^5\) It also contains an illustration of the above groupings by reference to a plot of altitude and MTOW for a small dataset of UAS at that time.\(^5^4^6\) In a manner similar to the EASA proposal, the methods used in the *Eurocontrol/IABG Report* identify (apparently by visual means) clusters of UAS in support of its proposed scheme.\(^5^4^7\)

2 Technical Approaches

*AAIF/Clothier et al*

Clothier (together with contributing researchers) has studied the question of UAS regulation since approximately 2006.\(^5^4^8\) Clothier’s earliest study considered the nature of the ELOS requirement that had been stipulated for UAS and how that requirement might be understood and quantified using mathematical and statistical methods.\(^5^4^9\) Follow-up work that year studied the risks involved with UAS operations closely,\(^5^5^0\) and further work in 2008 provided an overview of UAS regulations at the time, the diversity of UAS on offer and the lack of objective treatment (or understanding) of the risks of UAS.\(^5^5^1\) In

\(^5^4^5\) *Eurocontrol/IABG Report*, above n 488, 21.
\(^5^4^6\) Ibid 24, 25.
\(^5^4^7\) Ibid 24, 25.
\(^5^4^9\) Clothier and Walker, *Determination and Evaluation of Safety Objectives*, above n 47.
\(^5^5^0\) Clothier and Walker, *Casualty Risk Analysis*, above n 40.
\(^5^5^1\) Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 999.
doing so, Clothier proposed that a systems engineering approach could be applied to the management of risks and the design of regulations for UAS.\footnote{Ibid 1007.}

Clothier et al built on this work in 2010 and 2011, proposing a means by which an airworthiness certification regime could be developed in a more ‘systematic, objective and justifiable’ manner.\footnote{Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 871; See also Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3.} A key feature of the proposal concerned the structuring of a categorisation or classification of UAS, and the recognition of the importance of classification to the achievement of the overall objectives of the safety system in light of the diversity of UAS on their operations.\footnote{Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 872–879.} The proposal advocated the use of rigorous risk analysis based on reliable data concerning the current and projected UAS fleet.\footnote{Ibid 874.} A statement of first principles for effective regulation and classification emerged – ‘justifiable’, ‘flexible’, ‘systematic’, ‘objective’, ‘practicable’, ‘cognisant of costs’.\footnote{Ibid 872.} Similar principles were emphasised in other work.\footnote{Clothier, above n 53, 4; \textit{AAIF Report}, above n 11, 8-9.} The statements of principle led to the examination by Clothier et al of a classification scheme based on the potential of a UAS-AC to cause harm. The approach investigated the determination of type categories based on a combination of kinetic energy and ‘impact area’ (the area on the ground potentially exposed in a mishap, which is a function of numerous of the UAS-AC’s physical attributes) for over 500 UAS.\footnote{Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3.} Using this data, Clothier et al investigated the use of ‘defined limits’ of kinetic energy to establish groups.\footnote{Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 6.}

<table>
<thead>
<tr>
<th>Category</th>
<th>Description of loss outcome</th>
<th>Energy Limit (J)</th>
<th>Description of Energy Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UAS capable of causing non-fatal injury to one or more exposed people</td>
<td>KE\textsubscript{max} \times 42</td>
<td>&lt; 5% probability of causing a fatal injury to an individual standing in the open</td>
</tr>
<tr>
<td>2</td>
<td>UAS capable of causing a fatal injury to one or more exposed people</td>
<td>42 \leq KE\textsubscript{max} &lt; 1,356</td>
<td>\geq 5% probability of causing a fatal injury to an individual standing in the open</td>
</tr>
</tbody>
</table>

\footnote{Ibid 1007.}
3 UAS capable of causing a fatal injury to one or more people within a typical residential structure $1,356 \leq KE_{\text{max}} < 13,560$ $\geq 5\%$ probability of causing a fatal injury to an individual standing in the open

4 UAS capable of causing a fatal injury to one or more people within a typical commercial structure $KE_{\text{max}} \geq 13,560$ Capable of penetrating a reinforced concrete structure

Table 16: Clothier et al Kinetic Energy Classification Scheme

The authors observed that, on the basis that most UAS-AC with a mass of more than 20kg would have sufficient kinetic energy to penetrate most structures, the approach resulting in a classification in which category 4 covered a disproportionate mass range.\textsuperscript{560} The authors proposed that a ‘more objective approach’ would be to classify according to both kinetic energy and impact area using data clustering techniques that would ‘learn’ the type categories from the data (rather than to impose limits upon the data, as with the above approach).\textsuperscript{561} Amongst other things, this involved the determination of the most appropriate number of classes based on the data, which the authors determined (using an algorithm) to be 5.\textsuperscript{562} On that basis, the clustering process determined that category 4 should be split into two categories, such that the example classification derived was set out as follows:\textsuperscript{563}

<table>
<thead>
<tr>
<th>Category</th>
<th>Boundary Conditions</th>
<th>Example UAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$KE_{\text{max}} &lt; 42 \text{ J}$</td>
<td>Black Widow, Hornet</td>
</tr>
<tr>
<td>2</td>
<td>$42 \leq KE_{\text{max}} &lt; 1,356 \text{ J}$</td>
<td>Pointer, Raven</td>
</tr>
<tr>
<td>3</td>
<td>$1,356 \leq KE_{\text{max}} &lt; 13,560 \text{ J}$</td>
<td>ScanEagle, Aerosonde Mk4</td>
</tr>
<tr>
<td>4</td>
<td>$13,560 \text{ J} \leq KE_{\text{max}}$ $I_{\text{area}} &lt; 347m^2$</td>
<td>Shadow 600</td>
</tr>
<tr>
<td>4</td>
<td>$347m^2 \leq I_{\text{area}}$ [ie Impact Area]</td>
<td>Heron 1, Taranis, Global Hawk</td>
</tr>
</tbody>
</table>

Table 17: Clothier et al Revised Kinetic Energy Classification Scheme

\textsuperscript{560} Clothier et al, Definition of Airworthiness Categories, above n 3, 7.

\textsuperscript{561} Ibid 8.

\textsuperscript{562} Ibid.

\textsuperscript{563} Ibid 9. The term ‘$I_{\text{area}}$’ refers to the ‘hazard area’ or ‘impact area’ (that is, the exposed area on the ground) affected by a crashing UAS-AC. See Clothier et al, Definition of Airworthiness Categories, above n 3, 5-6.
Subsequent work evolved to focus squarely on the role of classification, noting classification to be foundational to effective UAS regulations.\(^{564}\) In that regard, the use of ‘clustering’ techniques derived from statistical algorithms designed to systematically sort UAS data into groups for the purposes of classification is also a notable development attributable in large part to Clothier et al.\(^{565}\) Clothier et al’s studies provide some of the most detailed consideration of the functioning of classification schemes in conventional and unmanned aviation that have been provided to date.\(^{566}\) This work includes a systems engineering and statistical analysis of the factors involved in classifying UAS and a sweep of the approaches taken internationally in relation to classification.\(^{567}\)

Clothier et al’s work has also been utilised within the report of the AAIF, which generated a report on a proposed certification framework in 2010.\(^{568}\) The report focuses on the need for a certification framework for UAS that focused on the risk measurements in determining the airworthiness requirements for specific UAS, as well as the areas of potential operation.\(^{569}\) Based on Clothier’s work,\(^{570}\) the AAIF recommended a classification scheme for UAS that incorporated both elements such that different ‘certification categories’ (1 to r) were available for UAS depending upon the increasing risks of the operation, which varied according to both the specifics of the UAS-AC (the ‘type categories’ on the x-axis) and the operational environment (depicted on the y-axis):\(^{571}\)

\(^{564}\) Palmer and Clothier, above n 36, 15; Clothier, above n 53, 2.
\(^{565}\) See generally Palmer and Clothier, above n 36.
\(^{566}\) Clothier et al, *Definition of Airworthiness Categories*, above n 3; Clothier 2011; Palmer and Clothier, above n 36.
\(^{567}\) Palmer and Clothier, above n 36.
\(^{568}\) *AAIF Report*, above n 11, 8.
\(^{569}\) Ibid 6-8.
Clothier et al have also proposed that this matrix could be extended in a third dimension so as to cover the possible categories of airspace that may be used by different types of UAS and UAS operations. This would provide a classification scheme that incorporates not just the risk to third parties on the ground, but also in the air. CASA appears to be analysing such recommendations for the purposes of possible incorporation into its forthcoming regime.

**DeGarmo/MITRE**

As mentioned above, DeGarmo’s study of UAS in 2004 remains one of the most comprehensive studies of UAS regulation issues to date. It was also amongst the first to analyse the role that classification would play in the development of regulations as a ‘fundamental first step’ and a ‘pre-requisite’. Although DeGarmo did not in fact propose a formal classification scheme, after noting the lack of consensus amongst the leading national authorities, he noted with respect to classification:

A suggestion is to base UAV classifications on a combination of the class of airspace needed for operations, autonomous kinetic energy values, and navigational accuracy (ability to stay [within]
prescribed airspace). Such a classification, while more complex than current schemes, will allow for the establishment of more refined definitions of vehicle characteristics which, in turn, will facilitate the development of system requirements, impose operational constraints, and define the level of access to the civil airspace system.\textsuperscript{577}

At the time, the expectation was that this work would be completed by approximately 2005.\textsuperscript{578}

\textit{Dalamagkidis, Valavanis and Piegl}

As with Clothier et al’s work, Dalamagkidis, Valavanis and Piegl’s studies represent early scientific consideration (since approximately 2008) of the various regulatory approaches being adopted towards UAS. The importance of classifying UAS in the process of regulation is also central to Dalamagkidis, Valavanis and Piegl’s work.\textsuperscript{579} Following a review of existing proposals, the authors propose the following classification:\textsuperscript{580}

<table>
<thead>
<tr>
<th>Class No.</th>
<th>Class Name</th>
<th>TGI</th>
<th>MTOW (kg)</th>
<th>Proposed Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Micro</td>
<td>$1 \times 10^2$</td>
<td>0-1</td>
<td>Generally unregulated due to minimal threat</td>
</tr>
<tr>
<td>1</td>
<td>Mini</td>
<td>$1 \times 10^3$</td>
<td>1-10</td>
<td>Regulated similarly to model aircraft</td>
</tr>
<tr>
<td>2</td>
<td>Ultralight</td>
<td>$1 \times 10^4$</td>
<td>10-100</td>
<td>Regulated according to ultralight requirements - FAR Part 103</td>
</tr>
<tr>
<td>3</td>
<td>Light</td>
<td>$1 \times 10^5$</td>
<td>100-1000</td>
<td>May be based on Light Sport Aircraft or FAR Part 23 (Normal Aircraft)</td>
</tr>
<tr>
<td>4</td>
<td>Normal</td>
<td>$1 \times 10^6$</td>
<td>1000-10 000</td>
<td>May be based on FAR Part 23 (Normal) or Part 25 (Transport)</td>
</tr>
<tr>
<td>5</td>
<td>Large</td>
<td>$1 \times 10^7$</td>
<td>10 000+</td>
<td>May be based on FAR Part 25 (Transport)</td>
</tr>
</tbody>
</table>

\textit{Table 19: Dalamagkidis et al Initial Classification Scheme}

\textsuperscript{577} Ibid 2-41.
\textsuperscript{578} Ibid 3-2.
\textsuperscript{579} Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50, 514 note that ‘a need arises to determine appropriate UAS classes for regulatory purposes’.
\textsuperscript{580} Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111, 324; The phrase ‘TGI’ refers to ‘Time between ground impacts’; that is, a measure of the reliability (or required reliability) of the UAS.
There are several critical elements to the above approach. First, as a risk-based approach, Dalamagkidis, Valavanis and Piegl’s work identifies a connection between the classification task and the risks involved with the different types of UAS and citing the need for the determination of the appropriate classes of UAS for regulatory purposes.\(^{581}\) The authors refer to historical safety data for conventional aircraft operations to calculate a meaning for the ELOS requirement, which is said by the authors to mean that UAS must exhibit a fatality rate of \(1 \times 10^{-7}\) per hour for ground impacts.\(^{582}\) By this means, a UAS risk model is created using the characteristics of the UAS in question (size, weight, kinetic energy) such that the expected fatalities anticipated will fall within the current level of safety exhibited for conventional aviation.\(^{583}\) The authors use this risk model to determine the required reliability for a small number of UAS based on their characteristics,\(^{584}\) and the authors observed an ‘approximately linear relationship’ between the mass of a UAS-AC and its required reliability.\(^{585}\) The authors therefore proposed that a ‘natural classification may be based on the order of magnitude of their MTOW, where each subsequent class will require an accident rate an order of magnitude smaller than the previous’.\(^{586}\) The translation of the risk study into the proposed classification is not fully described by the authors.

The specifics of the above approach have been developed in other work, and, notably, Dalamagkidis, Valavanis and Piegl\(^{587}\) published a further proposed classification scheme in 2008 using a similar methodology but with subtle variations:

<table>
<thead>
<tr>
<th>Class No.</th>
<th>Class Name</th>
<th>TGI</th>
<th>MTOM</th>
<th>Proposed Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Micro</td>
<td>(1 \times 10^2)</td>
<td>(\leq 0.200)</td>
<td>Generally unregulated due to minimal threat</td>
</tr>
</tbody>
</table>


\(^{582}\) Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111, 323.

\(^{583}\) Ibid.

\(^{584}\) Ibid.

\(^{585}\) Ibid.

\(^{586}\) Ibid.

CLASSIFYING UNMANNED AIRCRAFT SYSTEMS

Chapter IV

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Weight Limit</th>
<th>Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mini</td>
<td>1x10^3 ≤ 2.4</td>
<td>Regulated similarly to model aircraft</td>
</tr>
<tr>
<td>2</td>
<td>Small</td>
<td>1x10^4 ≤ 28</td>
<td>May be based on Ultralight, Light Sport Aircraft or FAR Part 23 (Normal Aircraft)</td>
</tr>
<tr>
<td>3</td>
<td>Light/Ultralight</td>
<td>1x10^5 ≤ 336</td>
<td>May be based on FAR Part 23 (Normal) or Part 25 (Transport)</td>
</tr>
<tr>
<td>4</td>
<td>Normal</td>
<td>1x10^6 ≤ 4000</td>
<td>May be based on FAR Part 25 (Transport)</td>
</tr>
<tr>
<td>5</td>
<td>Large</td>
<td>1x10^7 ≤ 47580</td>
<td>May be based on FAR Part 25 (Transport)</td>
</tr>
</tbody>
</table>

Table 20: Dalamagkidis et al Revised Classification Scheme

Of note is the inclusion of a ‘300% safety margin’ built into the required reliability to ensure the requirements are conservative and thereby err on the side of additional safety.\(^{588}\) This alteration to the classification construction illustrates the sensitivity of the exercise to the decisions made in relation to its composition. For instance, in the second scheme, significant shifts have occurred in relation to the proposed class boundaries when compared to the first classification proposal: a ‘micro’ UAS-AC may weigh only up to 200g (as opposed to 1kg), the ‘mini’ class has been reduced while the ‘light’ and ‘ultralight’ classes have been combined (and reduced from 1000kg to 336kg) and a new ‘small’ class has been included. It is notable that the class names have changed to accord with the proposed regulatory treatment (ie – the previously distinct ‘light’ and ‘ultralight’ classes have been joined, possibly to be regulated jointly). Thus, the study aligns with recognition of the importance of classification and an early iteration of a classification for UAS derived on a systems engineering approach and based upon mathematical and statistical analyses. It also demonstrates both the utility and the difficulty of designing a classification scheme using this kind of approach.

**Fraser and Donnithorne-Tait**

In 2010, Fraser and Donnithorne-Tait conducted an interesting study of UAS classification on behalf of the Canadian Centre for Unmanned Vehicle Systems which sought to

\(^{588}\) Ibid 514.
establish an ‘objective and mathematically rigorous approach’ to UAS classification. What emerged was a classification of UAS that utilised a risk metric to determine mass classes of UAS purporting to be ‘largely applicable in any jurisdiction, promoting international harmonization and increased safety of UAS operations’. That classification is stated to be as follows:

<table>
<thead>
<tr>
<th>UAS Class</th>
<th>MTOM</th>
<th>Impact Energy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Harmless UAS</td>
<td>≤50g</td>
<td>33.9</td>
<td>Aircraft that pose no risk of severe long-term injury to unsheltered population people</td>
</tr>
<tr>
<td>II Micro UAS</td>
<td>50g to 1.5kg</td>
<td>12.8</td>
<td>May pose a risk to unsheltered population but should not penetrate sheltering people</td>
</tr>
<tr>
<td>III Mini UAS</td>
<td>1.5kg to 10kg</td>
<td>49.9</td>
<td>Aircraft pose a risk to unsheltered population and may penetrate non-concrete</td>
</tr>
<tr>
<td>IV Small UAS</td>
<td>10kg to 500kg</td>
<td>-</td>
<td>Aircraft have potential to cause ground fatalities to sheltered population</td>
</tr>
<tr>
<td>V Large UAS</td>
<td>&gt;500kg</td>
<td>-</td>
<td>Aircraft functionally and operationally similar to manned commercial aviation</td>
</tr>
</tbody>
</table>

*Table 21: Fraser and Donnithorne-Tait Classification Scheme*

The authors approached the classification of UAS by considering the likely risk profiles of given UAS in terms of their mass, velocity, and reliability, as well as the population densities of the areas overflown. Accepting there to be a notional point (in terms of mass) at which unmanned aircraft ‘diverge appreciably such that manned aircraft regulations are no longer appropriate’, the authors defined a classification for UAS beneath that point of divergence (said to be 500kg). This point of divergence is ascertained by using data collected from a survey of existing UAS and light conventional aircraft. As such, in a similar vein to Clothier et al’s work, Fraser and Donnithorne-Tait seek proposals for UAS regulations that exhibit objectivity and are derived by reference to

---

589 Fraser and Donnithorne-Tait, above n 211, 157.
590 Ibid.
591 This table has been compiled from Fraser and Donnithorne-Tait, above n 211, 171, 173.
592 Fraser and Donnithorne-Tait, above n 211, 157.
593 Ibid 163.
594 Ibid 164.
595 Ibid 163.
data-oriented understandings of the risks. The work is notable for its recognition of classification as playing a central role in the development of regulations, its thorough attempts to both understand the basis upon which existing and proposed weight boundaries for UAS have been derived, and for making preliminary assessments as to the quality of such proposals. The authors’ concluded that there is no rational or analytical basis for several of the commonly used demarcations within current proposals.

**Maddalon/Hayhurst et al (NASA)**

Following on from earlier work in 2006, Hayhurst et al at NASA studied the topic of UAS classification closely in their 2013 report. Although the report does not propose a new classification of UAS, it is notable for the breadth of its consideration of the topic. In a similar vein to DeGarmo, Hayhurst et al have noted the establishment of a classification scheme for the certification of UAS to be critical to the progress of regulation. In that regard, the report found the creation of a certification framework for UAS was fundamental to achieving routine UAS operations. The report makes important contributions in terms of its study of the function of the existing certification regime, the incongruities between UAS and the existing system, the nature of classification generally and its role in ensuring effective regulation. Of particular interest is the recognition of the connection between UAS classification and the regulatory purposes at hand relating to risk management, in a similar vein to Clothier et al’s work set out above. The report is also notable for its study of the componentry of a classification scheme as it might apply to UAS, namely the consideration of classification ‘factors’ (such as UAS-AC mass, complexity, configuration, operational type etc., thus similar to the ‘classification

---

596 Ibid 157.
597 Ibid 159 – 162. Fraser and Donnithorne-Tait analyse the European, UK, US, Canadian and Australian approaches. See also the analysis in ibid, ch 4.
598 Fraser and Donnithorne-Tait, above n 211, 160.
599 Maddalon et al, Perspectives on Unmanned Aircraft above n 8. See the earlier work of Hayhurst et al, Unmanned Aircraft Hazards, above n 11.
600 See Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 1
601 Ibid 1, 15.
602 Ibid 6.
603 Ibid 1, 14.
604 Ibid 2, 3.
605 Ibid 5, 6.
criteria’ discussed in this thesis) and the difficulties of resolving the optimal factors for use in UAS classification. The study concluded that further work was warranted.

Two follow up papers by the NASA scientists are of note in terms of developing the topics noted in NASA’s 2013 paper. For instance, a further technical paper in 2014 includes a comprehensive investigation and analysis of the ‘classification factors’ used in conventional aviation and those proposed for use in UAS certification (some 15 factors in total) with a view to refining the possibilities for designing a classification scheme. The authors concluded to the effect that further research needs to be undertaken in relation to resolving the appropriate classification factors, integrating them, and synthesising the result into a certification regime. In that regard, a paper published by the authors contemporaneously with the 2013 report develops on that point in identifying the need for a UAS classification scheme to achieve ‘clarity, agreement and enforceability’ (in a similar vein to the ‘guiding principles’ enunciated by Clothier et al, set out above).

**Weibel and Hansman**

Weibel and Hansman at the Massachusetts Institute of Technology developed a UAS classification scheme as part of a comprehensive study of the integration of UAS into civil airspace in 2004. Amongst other things, the study collected and analysed physical and performance data relating to a small number of fixed-wing UAS to determine the existence of ‘natural breakpoints’ upon which to base the formulation of the classification. Five classes of UAS were established based on ‘a combination of research and military literature’, although no airworthiness rules were established by the study:

\[\text{\footnotesize{\textsuperscript{613}} See Weibel and Hansman, above n 47, 41 for the table. Note that Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 25 sets out a similar table.}}\]
<table>
<thead>
<tr>
<th>UAS Class</th>
<th>Representative Aircraft</th>
<th>Mass (lb)</th>
<th>Operating Area</th>
<th>Operating Altitudes (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro</td>
<td>Aerovironment Black Widow</td>
<td>Less than 2 lb</td>
<td>Local</td>
<td>Near-surface to 500ft</td>
</tr>
<tr>
<td>Mini</td>
<td>Aerovironment Pointer</td>
<td>2 to 30 lb</td>
<td>Local</td>
<td>100 to 10 000ft</td>
</tr>
<tr>
<td>Tactical</td>
<td>AAI Shadow 200</td>
<td>30 to 1000 lb</td>
<td>Regional</td>
<td>1500 to 18 000ft</td>
</tr>
<tr>
<td>MALE</td>
<td>General Atomics Predator A</td>
<td>1000 to 30000 lb</td>
<td>Regional/National</td>
<td>18 000ft to FL 600</td>
</tr>
<tr>
<td>HALE</td>
<td>Northrop Grumman Global Hawk</td>
<td>1,000 to 30 000 lb</td>
<td>Regional/National/International</td>
<td>Above FL 600</td>
</tr>
<tr>
<td>Heavy</td>
<td>McDonnell Douglas MD-11</td>
<td>&gt; 30 000lb</td>
<td>National/International</td>
<td>18 000ft to FL 450</td>
</tr>
</tbody>
</table>

Table 22: Weibel and Hansman Classification Scheme

There is not a great deal of information provided by the authors as to how the above classes are derived, save that it appears the authors consulted a dataset of UAS available at that time, determined the applicable weight limits by plotting performance attributes for MTOW, endurance, altitude, and speed in order to determine clusters (I assume the clusters were determined using visual observation).\(^{614}\) Having settled on the classification, the authors used historical aviation data (as in Clothier et al’s and Dalamagkidis, Valavanis and Piegl’s work) to determine a quantified value for the ELOS requirement, in the order of $1 \times 10^{-7}$ fatalities per flight hour.\(^{615}\) From there, population data for the US is used to generate a map of the likely areas in which UAS in the above classes (by reference to a representative UAS from each class, considered to be the prototypical member of the class) would be permitted while still maintaining the determined ELOS level.\(^{616}\)

3  **Legal Approaches**

The topic of classifying UAS has been arisen in several important legal studies relating to the regulation of UAS. In each case, classification has been recognised as being of particular importance to the progress of regulations, but there is little in the way of

\(^{614}\) See Weibel and Hansman, above n 47, 38-40.

\(^{615}\) Ibid 68.

\(^{616}\) Ibid 71-74.
detailed analysis. The following is an overview of the existing legal perspectives relating to the classification of UAS.

**Kaiser**

In 2006, Kaiser published an early study of UAS regulation noting the particular difficulties caused by the extraordinary variety of UAS and providing an overview of the common categories. Kaiser’s work in 2011 noted that there remained no agreement on a classification for UAS; the analysis therefore utilised the following classification:

```
<table>
<thead>
<tr>
<th>UAS Class</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro UAS</td>
<td>~200g to 2kg (est. or typically)</td>
</tr>
<tr>
<td>Mini UAS</td>
<td>Up to 20 to 35kg</td>
</tr>
<tr>
<td>Small UAS</td>
<td>&lt; 150kg</td>
</tr>
<tr>
<td>Medium</td>
<td>150kg to ~1000kg</td>
</tr>
<tr>
<td>Large</td>
<td>&gt; 1000kg</td>
</tr>
</tbody>
</table>
```

*Table 23: Kaiser Terminology Scheme*

Although the classification is not developed into a regulatory proposal, this work represents an important contribution by expressly acknowledging the close connection between the category of UAS in question and the assessment of regulatory and economic implications.

**Peterson**

Peterson’s study in 2006 dealt with the classification issue more directly as part of his comprehensive assessment of the emerging UAS regulatory domain. Peterson acknowledged the task of developing a classification scheme to be the ‘first issue’ to be addressed in regulating UAS, though his consideration focused specifically on the

---

618 The classification scheme arises from Kaiser, ‘UAVs and Their Integration’, above n 46, 166, nn 10-11.
question of operational rules for UAS, rather than certification issues directly. Nonetheless there are several important and relevant issues canvassed in the work. For instance, Peterson’s recognition of the role of classification in the existing aviation system coincides well with subsequent technical sources: ‘[a] classification scheme is important for UAV development to give operational parameters to system designers and manufacturers as targets to aim for in accessing an intended operational environment.’

Therefore, after observing the use of mass criteria, kinetic energy, and other more complex methods of distinguishing UAS amongst the regulatory work underway, Peterson proposed a classification of UAS based on airspace usage categories (rather than on the characteristics of the vehicle):

<table>
<thead>
<tr>
<th>UAS Category</th>
<th>FAA Regulation</th>
<th>Airspace Usage</th>
<th>Airspeed Limit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>14 CFR 91</td>
<td>All</td>
<td>None</td>
<td>Analogous to RC Models</td>
</tr>
<tr>
<td>II</td>
<td>14 CFR 91, 101, and 103</td>
<td>E, G, and non-joint use D</td>
<td>NTE 250 (proposed)</td>
<td>Non-standard aircraft that perform special purpose operations</td>
</tr>
<tr>
<td>III</td>
<td>None (AC 91-57)</td>
<td>G (&lt;1200ft AGL)</td>
<td>100 (proposed)</td>
<td>Capable of flying through all categories of airspace and confirms to Part 91</td>
</tr>
</tbody>
</table>

Table 24: Peterson Classification Scheme

This approach was based on the view that existing regulation should be followed as closely as possible (for instance, Peterson notes the similar classification approached used by the CAA at that time under CAP722). Because the classification is based on existing rules for conventional aviation, the approach is therefore said to have the benefits of simplicity and familiarity. Peterson also considered that this approach assisted in risk mitigation strategies.

---

620 Peterson, above n 5, 594.
621 Ibid.
622 Ibid.
623 See Peterson, above n 5, 596.
625 Peterson, above n 5, 598.
626 Ibid 595.
Plucken

Plucken’s study in 2011 considers the importance of classification in the regulatory context, specifically focusing on the role of certification and licencing of UAS,\(^{627}\) but expressly only deals with classification at a level of generality.\(^{628}\) Save for referencing the recognised types of ‘micro’, ‘small’, ‘medium’ and ‘large’ (similar to Kaiser’s adopted typology), it was beyond the scope of Plucken’s work to analyse the matter in sufficient detail to formulate a classification scheme.\(^{629}\) Useful contributions are made though in recognition of the connection between certification and classification, the role of classification in achieving international harmonisation, and the need to align classification development with risk assessment.\(^{630}\)

Other Legal Consideration

The other legal sources reviewed for the purposes of this thesis do not provide any critical analysis of classification in the context of certification or regulation, only touching on the issue in passing.\(^{631}\) Therefore, as it stands, there has been only limited study of UAS classification from a legal perspective.

---

\(^{627}\) See Plucken, above n 46, 26.

\(^{628}\) Plucken, above n 46, 25, 26 notes that it is only within the scope of study to ‘touch on’ classification.

\(^{629}\) See Plucken, above n 46, 25, 26.

\(^{630}\) Ibid 137-138.

\(^{631}\) See, eg, Bellows, above n 14, 611; Gogarty and Hagger, above n 220, 86-89; Kapnik, above n 127, 442-444; Marshall, above n 222, 694, 695; Masutti, above n 100, 1; Michaelides-Mateou and Erotokritou, above n 27, 121-123; Takahashi, above n 21, 513-514, Vacek, above n 185, 22.
V ASSESSMENT OF THE CURRENT APPROACHES TO UAS CLASSIFICATION

It is apparent from a review of the current approaches to classification outlined above that classification has been recognised either expressly or implicitly as an important issue in developing regulations for UAS since approximately 2001, and more specifically from 2004. Tracing developments through from this time, there is a distinct trend towards increasing awareness and scrutiny of the issue from technical perspectives, and a desire for the use of less ambiguous and more objective methodology. Although increasing scientific study has been brought to bear on the issue, and increasingly rigorous and sophisticated proposals have emerged, there remains no consensus and the question as to the appropriate approach remains an open even at the highest regulatory levels. Despite the volume of important work undertaken, it appears unlikely that mathematical or technical approaches alone will be able to resolve each and every aspect of the issue.

This Chapter assesses and draws together the conceptual development of UAS classification, summarises the current approaches reviewed in the previous Chapter and identifies within them the interesting trend toward more sophisticated classification tied to more sophisticated understandings of risk. Nonetheless, this Chapter concludes that current proposals lack the critical framework of reference necessary to vet the quality of the current proposals and frame constructive debate. Few proposals have conceived the classification task as a regulatory exercise that must result in effective law, and the absence of that critical conceptual step hinders progress.

A The Importance of Classification to UAS Certification

It is important to trace the developments in UAS classification over time, commencing with the brief coverage of the topic in the Eurocontrol/IABG Report of 2001, which

634 See the work of Clothier et al, Fraser and Donnithorne-Tait, Dalamagkidis, Valavanis and Piegl, NASA, Weibel and Hansman, above n 47.
635 See, eg, Clothier et al, Definition of Airworthiness Categories, above n 3, 9, 10.
identified the issue and noted that the mass of an UAS-AC would likely feature prominently in any classification. At this time few actual, civil regulations existed to test the theory; notably the Australian *CASK Part 101* supported the view. As further regulatory proposals spawned, technical and academic consideration brought the question of appropriate classification to the fore.

DeGarmo’s ground-breaking assessment of the issues to be addressed in integrating UAS into civil airspace in 2004 was the first to seriously consider the link between the development of a classification scheme for UAS and the progression of certification standards:

> Without an adequate classification scheme, consensus on regulations, standards and certification requirements will be made more difficult and international harmonization virtually impossible to obtain…

> …Arriving at consensus on a definition and classification scheme for UAVs will be difficult, but it is fundamental to progress in standards and regulatory development. The development of a classification scheme is especially important. While good reasons exist for current conventions, a single scheme should be adopted by all civil aviation authorities.

The same year, the AIAA echoed DeGarmo’s views, and the JAA similarly noted the importance of classification in its report, commenting on the fact that of the 15 existing proposals canvassed in the JAA’s review, 10 contained a categorisation of UAS. It is important to observe that up to this point in time most of the thinking towards UAS classification assumed UAS-AC mass to be the sole or primarily relevant criterion. In that regard, the JAA’s thinking was influential – it proposed the use of kinetic energy measurements and even more complex risk metrics to construct a classification of UAS that would enable correlations to be made with the arrangements for conventional aviation, thereby potentially achieving the ELOS mandate that it had pronounced. This work coincided with the views of the UK CAA exhibited in its ‘Light UAV Policy’

---

637 DeGarmo, above n 42, 2-40. These comments have been echoed more recently by Clothier et al, *Definition of Airworthiness Categories*, above n 3, 4.
638 JAA/Eurocontrol Report, above n 59, Enclosure 3, 9 (see above n 633); See also AIAA, above n 42.
639 See the *CASK Part 101* ref 101.240; *Eurocontrol/IABG Report*, above n 488; See Chapter IV.D above.
640 See JAA/Eurocontrol Report, above n 59, Enclosures, Appendix 3-4.
published in 2004, and also served as the basis for EASA’s follow-up work in the form of the 2005 EASA A-NPA.

The FAA (which had commissioned DeGarmo’s study) announced in 2006 that it too was a studying the question of classifying UAS, which coincided with the technical studies of UAS classification emerging from approximately 2005 from Weibel and Hansman, Clothier et al, Dalamagkidis, Valavanis and Piegl. Each of these studies focused on the need to develop a certification framework for UAS that used classification techniques to specify the characteristics, rights and requirements for each class.

Clothier et al in particular called for a closer examination of UAS type categories and the role of classifying UAS in the formation of regulations, stating that –

The specification of type categories for UAS will heavily influence the nature of the future civil/commercial UAS industry; hence it is likely the decision will involve multiple, competing stakeholders and be a predominantly discursive process.

Dalamagkidis, Valavanis and Piegl mirrored these sentiments, stating the ‘whole spectrum of UAS cannot fit in manned aviation classes… a need arises to determine appropriate UAS classes for regulatory purposes’. Similarly, Fraser and Donnithorne-Tait’s work in 2010 drew particular attention to the perceived lack of objectivity and the arbitrary nature of existing decision-making in terms of classification, as well as the potential for such decisions to undermine the effectiveness of UAS regulations. These studies signalled a

641 See Haddon and Whittaker, above n 176.
642 EASA A-NPA, above n 169.
644 Weibel and Hansman, above n 47.
645 Clothier and Walker, Determination and Evaluation of Safety Objectives, above n 47; Clothier et al, Casualty Risk Analysis, above n 40; Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22.
647 Clothier et al, Definition of Airworthiness Categories, above n 3, 10. Clothier et al have also noted that the ‘specification of type categories could have a significant influence on the future ‘shape’ of the civil UAS industry’, and further that ‘regulatory classification schemes can have a significant influence on the shape and viability of the industry’: Clothier et al, Definition of Airworthiness Categories, above n 3, 4; Palmer and Clothier, above n 36, 15.
649 Fraser and Donnithorne-Tait, above n 211, 157-158.
shift in thinking towards the need for more rigorous approaches to classification, and possible linkages to advances in safety science and risk assessment for UAS (and which has continued).

It is notable that around this time, industry-based standard-setting organisations such as ASTM International sought to formulate classification schemes for UAS (in the form of ‘terminology’) as an initial step in drafting regulations. Subsequent work by the AAIF in Australia articulated the classification issue even more clearly. The AAIF stated in 2010 that

[unmanned aircraft] come in a large variety of sizes, sensing capabilities and operational concepts.

The regulatory issues are intrinsically linked to the different classes of [unmanned aircraft].

The report went on to identify the determination of airworthiness categories as ‘the crux of the problem’ and to undertake a comprehensive consideration of the ways in which a UAS classification could be developed based upon risk data and analysis (together proposing its own solution). This coincided with a more acute focus amongst the technical writing on the question of classification more specifically, rather than the broader focus on certification and risk management (for instance, specific studies undertaken by Clothier et al from approximately 2013). In that regard, the shift toward more sophisticated risk assessment and more sophisticated classification has not altered the perception that classification remains the first step in order to enable subsequent development of standards that can be tailored to the classes.

The NASA studies of 2013 and 2014 dedicated significant resources to the task and provided the most comprehensive analysis of the role of classification in existing

---

650 ASTM International, above n 528, 1; See also AIAA, above n 42, iv.
651 AAIF Report, above n 11, 2 (emphasis added).
653 See, eg, Palmer and Clothier, above n 36; Clothier, above n 53.
654 See, eg, Palmer and Clothier, above n 36, 7.
regulations and its possible role in UAS certification. The NASA studies nonetheless concluded that the task was ‘more complicated than it may appear’. These sentiments are reflected in Clothier’s comment that there is a ‘plethora of existing classification approaches’ and the question as to ‘why haven’t they been taken up?’ The fact that more than a decade has passed since the issue was first identified as of critical importance by DeGarmo speaks volumes about the difficulties being encountered by current regulatory efforts. These difficulties are patent in the vast discrepancies between the current approaches even with respect to the basic features of classification (to which this thesis now turns).

B The Core Aspects of Classification: Purposes, Methods, Structures and Key Decisions

As the predominance of the current approaches to UAS classification are technical in nature, the lack of legal analysis of UAS classification means there is no ready tool available to conduct an examination from a legal perspective – a problem which this thesis seeks to address. Thus, this section draws on the ‘core aspects’ of classification that can be observed in the current proposals – that is, the purposes, methods and structures that underlie the design of a classification scheme, and the key decisions that need to be made in reducing such a scheme to writing (as law). These concepts are derived from the work of Brennan (a criminologist) and Starr (a sociologist) and I have explained in further detail in Chapter VI how this work can be used to align the technical and legal approaches to classification and ultimately generate a framework of reference to guide further work. For the moment, it suffices to elaborate on the core aspects of classification so that a full comparison of the disparate, current approaches can be undertaken.

655 Maddalon et al, Perspectives on Unmanned Aircraft above n 8; Hayhurst et al, Review of Current and Prospective Factors, above n 214; Maddalon et al, Considerations of Unmanned Aircraft, above n 49.
656 Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 16.
657 Clothier, above n 53, 17.
658 Brennan, above n 470, 201.
659 Starr, above n 55.
1 Purposes

In Tim Brennan, ‘Classification: An Overview of Selected Methodological Issues’ (1987) 9 Crime and Justice 201 the author identifies 6 primary purposes of classifications: description, prediction, discovery, analytical, theory confirmation, and taxonomic. He notes:

A classification cannot be expected to fulfil purposes for which it was not created… Different purposes require different methods, and different data will usually produce different classifications. Minor changes in purpose can produce dramatically changed classifications of the same objects… Vagueness or confusion about research purposes may undermine the potential of recent methodological advances. Thus a clarification of purpose is important prior to the selection of methods.660

Descriptive (or epidemiological) Classification

Classifications allow for the simplification and summarisation of complex data and phenomena so that general statements can be made about each class.661 Classification facilitates the efficiency of knowledge exchanges, sometimes called ‘cognitive economy’,662 because mental effort is minimised where features (presumably the relevant features) of each class are distilled from an infinite variety to a more manageable number and thereby communicated or learned.663 Information about each individual class member is lost along the way, and ideally, only the ‘salient’664 information is retained so that a class can ‘describe’ or act as a proxy for the characteristics of the individual members.

Discovery of new typologies

Sometimes classifications are used simply in order to discover useful trends in data rather than to test any particular theory. This process may elucidate ‘hidden structures’ or

660 Brennan, above n 470, 203 (citations omitted).
661 Ibid 185 citing Sokal, above n 43.
662 Brennan, above n 470, 203; See also Sokal, above n 43, 1116.
663 Brennan, above n 470, 203.
664 Ibid.
relationships present within the data, and it may allow for the discovery of new types not previously observed. 665

**Predictive classifications**

Classifications may also have predictive power in that, having identified groups based on relevant features, the scheme may predict future behaviour or tendencies of the members relevant to the task at hand. In so doing, the classification may not describe or explain the phenomena at all, but may nonetheless have practical application as a predictive device. 666

**Creating analytical entities or ideal types**

In terms of analytical classifications, a classification may create new conceptual or ideal types (based on inferences) that can then be subjected to further research or experimentation or explanation. 667 In that regard, classifications may be a tool for learning and exploring pre-defined concepts or phenomena. 668

**Theory Confirmation and Model Testing**

Classifications may also be used to test and confirm (or not) predefined theories and concepts by analysing data pertaining to the relevant phenomena. 669 In that way, statistical methods can be used to scrutinise, ‘unravel’ 670 and explain the alignment between an existing classification and the characteristics or theories that it purports to describe. 671

**Nomenclative classification**

Finally, nomenclature often follows from classification by attaching names to classes. Brennan states that ‘every discipline shares a professional dictionary of terms, names and

665 Ibid 204.
666 Ibid.
667 Ibid 205.
668 Ibid 205. See the approach taken by Clothier et al where clustering algorithms are used to learn potential type categories of UAS, and in other work whereby classification techniques are used as an ‘exploratory analysis tool’: See Clothier et al, Definition of Airworthiness Categories, above n 3, 6; Palmer and Clothier, above n 36, 3.
669 Brennan, above n 470, 206.
670 Ibid.
671 Ibid.
concepts', and thus, the features of established classes come to be synonymous with the labels attached to them over time through a course of usage. Nomenclature is therefore a central feature of any classification due to its criticality in facilitating the communication, storage, and retrieval of information.

2 Methods

Approaches to classification have evolved with social advances, particularly in scientific thought and technological innovation, which have provided both increasing amounts of information as well as new methods of assessing this information. As a result classificatory methods have become increasingly sophisticated over time. Principal amongst these developments for classification is the use of statistical and clustering software designed to enable the processing of large amounts of information about a group of objects. Without such assistance, classificatory methods have been traditionally limited in ambit to methodologies that group objects according to only a few variables (partly because that is all that can be visually determined) and comprised of classes defined by the presence of each chosen variable.

Brennan notes the movement in studies in criminological classification towards quantitative multivariate methods in search of classifications that are of ‘higher scientific quality’. These methods classify groups of objects based on multiple variables that would be effectively impossible to consider without computer assistance, including the use of clustering algorithms that may result in polythetic classifications; that is, classifications of objects in which similarities are gauged by overall similarity and groups may not be characterised by commonality across all or any particular variables. Brennan

672 Ibid 207.
673 Ibid 208.
674 Brennan, above n 470, 239; Sokal, above n 43, 1112.
675 Sokal, above n 43, 1115, 1116.
676 Brennan, above n 470, 239. Note Brennan’s comment that ‘it is well known that human beings have a limited ability to process a large amount of information’.
677 Brennan, above n 470, 213.
678 See the use of computer assisted models and tools in Clothier and Walker, Determination and Evaluation of Safety Objectives, above n 47; Clothier and Walker, Casualty Risk Analysis, above n 40; Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111; Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50; Weibel and Hansman, above n 47.
679 Brennan, above n 470, 215.
notes that the presumed benefits are that these methods produce ‘higher objectivity, greater precision in measurement, higher information content and a general improvement in descriptive, predictive and theoretical validity’, though also noting that it is questionable whether these benefits can or will be achieved. The reader is referred to Brennan’s detailed description of the various specific methods in which he describes the mathematical, algorithmic and statistical methods of partitioning and clustering.

3 Structures

Classification schemes are knowledge structures in that they transmit information to a user about a group of objects under consideration. In this section provide an overview of classificatory structures that may be observed within a given classification scheme. Brennan defines 7 classificatory structures: monothetic, polythetic, natural, artificial, subjective, theoretical or conceptual; these aspects may also be evident in the methods used by the scheme as there is a connection between the concepts. Monothetic classifications are those in which distinctions between the objects under consideration are created based upon an attribute or attributes common to all objects; classes are established by reference to ‘cut-off’ points such that classes are contiguous. The task of assigning objects to particular classes is then a relatively simple one given that there are few variables at play and no overlap between classes.

On the other hand, polythetic classifications are more complex. This is primarily due to the multivariate nature of such classifications and the reference to any number of attributes in order to assess similarity between objects on a much broader basis (more akin to ‘family resemblance’ or perhaps, overall likeness). As such, not all members of each class will share each and every attribute. It follows from this that the classification scheme resulting may look (visually) very different, creating ‘fuzzy’ boundaries rather than

680 These are claims similar to those sought by Clothier et al and Fraser and Donnithorne-Tait: See, eg, Clothier et al, Definition of Airworthiness Categories, above n 3, 6, 7; Fraser and Donnithorne-Tait, above n 211, 157-158.
681 Brennan, above n 470, 213.
682 Ibid 221-231.
683 Ibid 214-221.
684 Brennan, above n 470, 215.
685 Ibid.
686 Ibid.
concrete cut-offs as well as observing ideal types or exemplars for each class. For that reason, polythetic classifications are generally regarded as ‘more natural’, in that they – to borrow from Brennan – examine ‘what the data have to say’. Classifications that proceed in this manner are regarded as natural, or intrinsic, in that generally speaking they discover order amongst the objects. This is to be contrasted with an ‘artificial’ classification, which proceeds by imposing an order on the objects being classified from the outset. In that regard, the distinction may be regarded as being one of the intrinsic and extrinsic creation of classes.

Brennan notes the suggestion that although ‘all classifications are abstract, purposeful, and, to some extent, artificial’, the point is that natural classifications attempt to ‘cleave’ as far as possible to the ‘reality’ disclosed by the objects of study, and in so doing the boundaries between classes ought to ‘reflect important natural difference’. Of course, not all classifications can be described as natural. Some, which Brennan describes as ‘subjective’, are characterised by an ‘almost total absence of formal statistical methods’ Others impress an external order by reference to an underlying theoretical perspective which dictates the selection of variables and boundary conditions. That is not to say, however, that any particular type is prima facie any ‘better’ than another, for the reason that such an assessment is inextricably linked to the purpose of the classification, which ‘guides the selection of classification structures as well as evaluative criteria’.

In any event, regardless of the approach to classification adopted, the structural elements of the classification can also be explained by reference to vertical and horizontal

---

687 Ibid 216.
688 Ibid.
689 Ibid.
690 Ibid 204.
691 Ibid 216.
692 Brennan, above n 470, 216.
693 Ibid.
694 Ibid.
695 Ibid.
696 Ibid 222.
697 Ibid 214.
structures, decisions in respect of which will influence the ‘cognitive economy’ or ‘adequacy’ (efficiency and ease of use) of the classification. First, the ‘vertical structure’ is defined by the hierarchical relationship between classes and subclasses within the scheme. As Brennan notes, hierarchies function through the vesting of increasing levels of information in every sub-class. In that manner, each tier displays less abstraction than the tier above it and thereby the scheme increases in precision. Consequently, the ‘cognitive load’ required to utilise the classification increases where hierarchies are involved. That said, hierarchies are important and familiar informational tools utilised in many contexts.

The ‘horizontal structure’ similarly affects the way in which a classification scheme is understood by users. The term refers to relationships within and between classes within the same tier, which Brennan notes is a question of ‘internal homogeneity’ such that objects within classes are similar, and dissimilar to objects in other classes. Stated simply, this is a defining and important characteristic of a classification scheme.

4 Key Decisions

Both Brennan and Starr assess the concept of a classification scheme as being comprised of a number of elements or decisions. While Brennan’s work usefully explains one view of the ‘inner workings’ which assists in understanding the processes at play, for present purposes Starr’s work more usefully describes a classification scheme as comprising a series of practical decisions or ‘preferments’; namely:

(a) the definition of a ‘domain’; this is, the selection of the relevant variables, attributes or characteristics to be used in classifying;

---

699 See Chapter VII.E.2 for related discussion on this point.
700 Brennan, above n 470, 218.
701 Brennan, above n 470, 219.
703 Brennan, above n 470, 220.
704 This is the word used by Starr: Starr, above n 55, 279 citing Goodman, above n 55, 32. Note that NASA proposes a different way of understanding or analysing UAS classification, by reference the ‘classification bases’, comprised of several ‘classification factors’: See, eg Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 13.
(b) grouping the objects in question by putting individuals into sets;
(c) naming the classes; and
(d) ordering or ranking the classes.

These decisions, in essence, form the basis for the articulation of the 4 key decisions outlined above for UAS classification (note that a graphical representation of the key decisions - overlaid on the *CASR Part 101* classification scheme – is presented in Chapter VIII).

**Criteria**

Given the consequences attaching to legal classifications, the decision to regard certain attributes as being relevant to the determination of rights and obligations is an important one. As noted above by Chief Justice Taft, the question as to the relevance of one attribute or another is one that must be judged by ‘the purposes at hand’. As Starr notes, ‘domains’ do not exist by their own right – they are chosen from amongst the many differences that can be observed across society. The process is one by which the specifics and unique characteristics of individual objects are deliberately ignored, in favour a simplified set of ‘relevant’ characteristics. This involves ‘conceptualizing the underlying principle’: what are we classifying and why? Choosing the relevant criteria involves a decision as to which characteristics best serve the chosen, or given, ends. As an example, NASA has stated that in addressing airworthiness certification ‘each organization develops a classification basis to address the risks that they deem most relevant to safety’. In conventional aviation regulation, mass has typically been used as a criterion, for instance. The words ‘attribute’ or ‘characteristic’ might also be used.

**Boundaries**

Having made the initial determination as to domain, groups need to be established according to variations in the chosen characteristic(s). There are many ways to define

---

706 Starr, above n 55, 279.
707 Ibid.
groups; for instance, some of the methods and structures discussed by Brennan may result in fixed ‘cut-offs’ along the spectrum of the chosen attribute being specified. For instance, in conventional aviation, mass limits such as 5760kg can be observed, as noted above. However, sometimes classes are based around a ‘prototype’ or ‘exemplar’ object that represents the classic ‘type’ for each group. Rather than fixed boundaries, ‘fuzzy’ boundaries may be utilised whereby classes may actually overlap in parts, rather than be mutually exclusive or discrete.\footnote{Starr notes however that ‘[b]ureaucracy and law press towards formal definitions’, sometimes called ‘bright line’ definitions. In official classifications, class membership is a point of particular concern, and one which is both influenced by the self-perceptions of those affected by the classification, and at the same time, self-perceptions are influenced by the creation of official classes.\footnote{As described above, the methods involved in creating a classification play a critical part in determining whether decisions as to class boundaries are made arbitrarily, upon some research theory or guiding principle, or through the use of data-driven observations and automated clustering.}}

**Designations**

Having chosen the relevant criteria and specified boundaries, the importance of naming the created classes is often overlooked. Starr notes that ‘by virtue of the web of associative memory, names call to mind other objects and events and [colour] the perception of any category’.\footnote{As Brennan says, ‘we cannot avoid naming for use in communication, information storage and retrieval’. This is significant: poor naming choices can undermine the effectiveness of the entire classification scheme. It is important to ensure that the chosen names actually describe the relevant characteristics of the objects in a class, and indeed their place in the overall classification scheme. Conversely, naming systems can be undermined by poor class definitions and other factors in the classification.}

\footnotesize

710 Starr, above n 55, 280.
711 Ibid 264, 273, 288.
712 Ibid 273.
713 Ibid 282.
714 Brennan, above n 470, 208.}
process. To illustrate, it would be counterintuitive to label a class as ‘unrestricted’ if in fact that class was highly restricted. It is critical from a legal perspective that the terms used to describe UAS must not mislead; if this cannot be achieved because of the proliferation of ‘vendor specific nomenclature’ and ‘marketing hype’ mentioned above then, perhaps, numbers ought to be used to describe classes.

Ordering or Ranking of Classes (or Applicable Rules)

It is critical to emphasise that unless classes are subjected to some form of ordering or arrangement, no classification scheme arises. In that regard it is true that ‘to admit all classifications on an equal footing amounts to no classification at all’. For instance, if classes A, B, C and D were created, but no rules or arrangement created, there would be no clear consequence to membership. The purpose of having conducted a classification would be defeated. In that regard, it should be noted that it is therefore difficult to approach the design of a classification scheme without reference to the arrangements and rules that may apply to the proposed classes, and, conversely, it is difficult to develop substantive rules without reference to established classes:

Classification presupposes objects that are to be classified, categories into which the objects are to be grouped, and some means of separating the objects into categories. In most realistic circumstances, classification also assumes a purpose for the classification, something to be accomplished other than arranging the objects into neat piles.

Just as there is a noted interrelationship between the purposes, methods and structures of a classification, it is apparent that this interrelationship also reflects in each of the key decisions. This is an aspect of the fact that classification (as a concept) refers to a process or investigation, the result of the process, and actual use of the resulting scheme. As such,
classifications are subject to constant scrutiny and adjustment; official classifications are products of their environment and are affected by those creating and using them.720

C  Current Approaches have not Resulted in Consensus

By reference to the core aspects of classification set out above, it is apparent from a review of the current approaches in Chapter IV that there is limited consensus in relation to each element.

1  Lack of Consensus as to the Purposes, Methods & Structures in Current Approaches

Purposes

There is no generally accepted definition as to the purposes of classifying UAS amongst the current approaches: in most cases, the purposes are not expressly stated, in others the purposes are said or assumed to be related to the task of producing a certification regime for UAS. The instances in which the precise purpose of classifying UAS is considered are rare, particularly amongst the regulatory proposals. The notable exceptions are the approaches of the AAIF,721 Clothier et al,722 and NASA723 which provide relatively comprehensive commentary on the connection between classification and certification. These approaches also recognise the relationship between classification and risk assessment.724 However, the statements of purpose have not been fully analysed or utilised as guidance in relation to the other core aspects of UAS classification (such as the methods, structures and key decisions) to the level suggested in Brennan’s work, which notes the integral role of purpose in classificatory design.725

Methods

There is an apparent lack of uniformity amongst the methods used to construct the various classification schemes reviewed. For instance, a number of the classification schemes have

720  Starr, above n 55, 264.
721  AAIF Report, above n 11, 6-8.
722  Clothier et al, Definition of Airworthiness Categories, above n 3, 4.
723  Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 4, 6.
724  See, eg, Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 4.
725  Brennan, above n 470, 202, 203.
apparently been constructed using arbitrary methods, without reference to any form of
data analysis or study: see the CASA, AIAA, and ASTM approaches. Similarly, the
JAA/EASA and Eurocontrol/IABG approaches utilise studies of UAS data in an attempt to
find groupings of UAS, but having plotted the data, proceed to make visual assessments of
the clusters or groups without any kind of mathematical assistance. In that regard I have
noted the definite trend towards the use of formal, statistical and mathematical approaches
to UAS classification question such as those apparent in AAIF/Clothier et al,
Dalamagkidis, Valavanis and Piegl, Fraser and Donnithorne-Tait, and Weibel and
Hansman. Nonetheless, somewhat subjective (visual) and arbitrary methods of discerning
clusters can be observed in the otherwise mathematical approaches in Dalamagkidis,
Valavanis and Piegl, Fraser and Donnithorne-Tait, and Weibel and Hansman. This can be
contrasted with the investigation of algorithmic clustering techniques in the work of
Clothier et al where statistical and mathematical tools are used to generate clusters. 726

Structures

In terms of classification structures, this trend towards ‘mathematically rigorous’ 727
approaches to UAS classification coincides with the study of the risk factors for UAS on
broader bases, beyond the more traditional criteria (for instance, weight and speed) to
more complicated, multi-factor risk analyses. These trends are evident in the work of
AAIF/Clothier et al, Dalamagkidis, Valavanis and Piegl, Fraser and Donnithorne-Tait and
endorsed in the studies conducted by NASA with the conclusion that further work is
warranted in relation to such methods. 728 However, there remains a lack of consensus on
the particular risk factors that ought to be utilised, with many approaches deferring to the
use of mass as a default option for classifying UAS through the adoption of boundaries
already existing in aviation regulation. As set out below, certain opinions suggest the
usage of existing mass boundaries is scientifically questionable, and the reason for using
mass is often poorly explained in the relevant proposal. Thus there is limited consensus as
to the appropriate structures in terms of the vertical hierarchies utilised and the horizontal
groupings (for instance the number of groups and sub-groups, their defining features and

726 See, eg, Clothier et al, Definition of Airworthiness Categories, above n 3, 8.
727 Fraser and Donnithorne-Tait, above n 211, 157.
728 Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 13.
relationships), and therefore an inability to reach consensus on which UAS are actually ‘similar’ for certification purposes.

2 Lack of Consensus as to Key Elements

Criteria

A comprehensive review of classification criteria utilised in the current approaches is undertaken in Appendix 1; it can be stated here that the selection of classification criteria is a critical decision to be made when undertaking the classification process. By ‘classification criteria’ I mean the choice of the relevant attributes or characteristics of UAS by which they are to be distinguished. As noted above, the importance of establishing type categories for UAS has been widely acknowledged to date. However, consensus on that issue has not resulted in consensus as to the characteristics of UAS that are relevant to the task. Having regard to the current approaches to classification reviewed in Chapter III, the determination of similarity, or dissimilarity, of UAS has been proposed to occur according to one or more of the following:

(a) physical attributes of the UAS-AC;
(b) performance attributes of the UAS-AC;
(c) wing configuration of the UAS-AC.

729 See the use of the term ‘criteria’ in JAA/Eurocontrol Report, above n 59, Annexure 3-1, 8-10. Palmer and Clothier use the term to refer to the conditions by which classes are created (that would encompass a consideration of class boundaries which is broader than the usage of the term herein): See Palmer and Clothier, above n 36, 8.

730 This is implicit in Palmer and Clothier’s statement that the choice of attribute (criteria) depends on the regulatory context in which the classification scheme is to be used: Palmer and Clothier, above n 36, 2; See also Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 13.

731 Clothier et al also refers to ‘attributes’, whereas NASA refers to ‘classification bases’ and ‘factors’: See Palmer and Clothier, above n 36, 2; Cf Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 13 – 15.

732 See generally Maddalon et al, Perspectives on Unmanned Aircraft above n 8, 14.


734 See the approaches of CASA, FAA, TC, Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50; Weibel and Hansman, above n 47, ASTM International, above n 528; Fraser and Donnithorne-Tait, above n 211.

735 See, eg, the approach of the AIAA, above n 42.

736 See, eg, the approach in CASR Part 101.
(d) operating environment or airspace usage;\textsuperscript{737}
(e) level of autonomy possessed by the UAS;\textsuperscript{738}
(f) commercial or recreational application;\textsuperscript{739} or
(g) risk profiles of the UAS.\textsuperscript{740}

There may be additional means of distinguishing UAS – one analysis has identified 16 possible criteria,\textsuperscript{741} another identified 20.\textsuperscript{742}

The major point of disagreement at present is as to whether the mass of the UAS-AC ought to be the primary criterion in classifying UAS, or whether other measures of risk such as kinetic energy or more complex risk metrics are more appropriate. The below table summarises the use of criteria in the proposals referred to above:\textsuperscript{743}

<table>
<thead>
<tr>
<th>Source</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASA</td>
<td>Mass of UAS-AC (Proposed boundaries based on risk metric)</td>
</tr>
<tr>
<td>TC</td>
<td>Mass of UAS-AC / Range of UAS-AC</td>
</tr>
<tr>
<td>CAA</td>
<td>Mass of UAS-AC</td>
</tr>
<tr>
<td>FAA</td>
<td>Mass of UAS-AC\textsuperscript{744} / Speed of UAS-AC\textsuperscript{745}</td>
</tr>
<tr>
<td>AIAA</td>
<td>Operating Altitude of UAS-AC / Endurance of UAS-AC</td>
</tr>
<tr>
<td>ASTM</td>
<td>Mass of UAS-AC</td>
</tr>
<tr>
<td>EASA</td>
<td>Kinetic Energy of UAS-AC / Operational Categories</td>
</tr>
<tr>
<td>Eurocontrol</td>
<td>Mass of UAS-AC / Endurance of UAS-AC / Altitude of UAS-AC</td>
</tr>
<tr>
<td>AAIF/Clothier</td>
<td>Risk equation for UAS-AC / Operational Environment</td>
</tr>
<tr>
<td>Dalamagkidis</td>
<td>Mass of UAS-AC (based on a risk equation)</td>
</tr>
<tr>
<td>Fraser</td>
<td>Mass of UAS-AC / Kinetic Energy of UAS-AC (based on risk metric)</td>
</tr>
</tbody>
</table>

\textsuperscript{737}See, eg, the approach of Peterson, above n 5.
\textsuperscript{738}See, eg, the approaches of DeGarmo, above n 42; \textit{Eurocontrol/IABG Report}, above n 488.
\textsuperscript{739}See, eg, the approaches of CASA, TC, FAA. It is not within the scope of this thesis to further evaluate the use of such a distinction; this thesis is primarily concerned with UAS for commercial purposes.
\textsuperscript{740}See Clothier et al, Definition of Airworthiness Categories, above n 3, \textit{AAIF Report}, above n 11, Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50; Fraser and Donnithorne-Tait, above n 211; Weibel and Hansman, above n 47.
\textsuperscript{741}Korchenko and Illyash, above n 652, 28.
\textsuperscript{742}Maddalon et al, Considerations of Unmanned Aircraft, above n 49, 8-13.
\textsuperscript{743}Note that Maddalon et al, Perspectives on Unmanned Aircraft above n 8 produces a similar table, but based on the authors’ views as to the relevant ‘classification factors’ in issue.
\textsuperscript{744}Pursuant to the \textit{FMRA}; \textit{sUAS ARC Report}, above n 521.
\textsuperscript{745}Pursuant to the \textit{sUAS ARC Report}, above n 521.
It is apparent that current approaches, particularly those proposed by the regulators, favour the use of a mass criterion (sometimes alone but often together with other factors). Mass is a natural, predominant, simple, and familiar means of distinguishing aircraft given experience with conventional aviation, where mass is used to indicate passenger numbers and likely magnitude of risk in order to drive reliability standards. Although numerous sources cite mass as a being a good predictor of risk, and/or a good predictor of other relevant characteristics of the UAS-AC (that is, it is said that mass can or may act as a proxy in describing the relevant traits of a UAS-AC), there is a growing recognition that mass may not be an appropriate indicator of risks for UAS given the many differences. In that regard, it is notable that most of the proposals generated by the academics and scientists referenced in this thesis seek to understand and explain risks in more complex terms than simply by reference to mass. It seems inevitable that the increasing complexity of risk metrics may improve accuracy in risk understandings (in a __________)

---

Table 25: Comparison of Criteria used in Current Approaches reviewed in Chapter IV

<table>
<thead>
<tr>
<th>Weibel</th>
<th>Mass / Kinetic Energy / Operating Area / Altitude of UAS-AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiser</td>
<td>Mass of UAS-AC</td>
</tr>
<tr>
<td>Peterson</td>
<td>Airspace Categories</td>
</tr>
</tbody>
</table>

---

746 See AAIF Report, above n 11, 8; Clothier et al, *Definition of Airworthiness Categories*, above n 3; See Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 14.
747 See generally Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 14; Clothier et al, *Definition of Airworthiness Categories*, above n 3, 7; See also Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50, 514.
748 Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 14; Maddalon et al, *Considerations of Unmanned Aircraft*, above n 49, 6. See also Kaiser, ‘UAVs and Their Integration’, above n 46, 165.
749 Fraser and Donnithorne-Tait, above n 211, 170.
750 Noting of course that even in existing regulations, certification does involve considerations beyond just mass: Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 6. See also Maddalon et al, *Considerations of Unmanned Aircraft*, above n 49, 4.
752 See Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 6, 14, 16.
755 Clothier et al, *Definition of Airworthiness Categories*, above n 3, 7; AAIF Report, above n 11, 8; Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 6; Palmer and Clothier, above n 36, 241.
sense) that can be used in classification but at the cost of the user-friendliness of the scheme. 757 Few have studied the nature of the trade-offs involved, 758 and as it stands there remains no consensus as to the most appropriate risk metric: NASA’s own study concluded that ‘the identification of factors important to UAS classification is not clear cut’. 759

**Class Boundaries**

Once the criteria or attributes relevant to the exercise have been chosen, lines must be drawn across the spectrum of the criteria in order to create classes. 760 The issues concerning the selection of boundaries for UAS regulation are set out in detail in Appendix 2. Great care must be taken when making decisions in this regard because the rights, obligations and costs are at stake for manufacturers and operators of UAS depending on which side of the line a particular UAS falls. Therefore, selecting the ‘boundary conditions’ 761 that apply to each class is a point of particular contention for UAS operators. Unfortunately, there is no consensus as to how these decisions ought to be made. 762 The table below shows the mass boundaries proposed amongst the current classification proposals reviewed in Chapter IV, and highlights the extent of the disparity. 763

---

757 See, eg, Clothier and Walker, *Casualty Risk Analysis*, above n 40, 4; DeGarmo, above n 42, 2-40.
758 See, eg, Clothier et al, *Definition of Airworthiness Categories*, above n 3, 4; Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 880; Palmer and Clothier, above n 36, 14; See also Peterson, above n 5, 595.
759 Maddalon et al, *Perspectives on Unmanned Aircraft* above n 8, 15.
760 Starr, above n 55, 273.
763 The UVS International classification scheme (set out in Chapter II.A.2) is utilised as a point of comparison against industry understandings.
As noted above, UAS display a wide variety of characteristics across their physical attributes, due largely to the unique design parameters and possibilities of the unmanned configuration. This diversity reflects in the current proposals in terms of the definition of class boundaries for UAS. Broadly speaking, the current proposals (including those forming part of Figure 1) exhibit five general methods of determining UAS boundary conditions:

(a) adopting the mass boundaries in existing regulations;
(b) translating the mass boundaries in existing regulations into new boundaries for UAS;
(c) proposing new boundaries for UAS arbitrarily;

For UAS there is a closer relationship between its design and its application than is evident for conventional aircraft: See Kaiser, ‘Legal Aspects of UAVs’, above n 83, 345; Palmer and Clothier, above n 36, 15.

See generally AAIF Report, above n 11, 11; Fraser and Donnithorne-Tait, above n 211, 163.
proposing new boundaries for UAS based on risk analyses;\textsuperscript{766} or
proposing new boundaries for UAS by observing ‘natural’ groupings according to
data concerning UAS.\textsuperscript{767}

Decisions made in this regard have a high degree of influence on the overall classification
scheme.\textsuperscript{768} The current approaches to boundary selection evident in the proposals
reviewed in Chapter IV can be summarised as below:\textsuperscript{769}

<table>
<thead>
<tr>
<th>Source</th>
<th>Class Boundaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASA\textsuperscript{770}</td>
<td>Arbitrary/empirically derived</td>
</tr>
<tr>
<td>TC</td>
<td>Adoption of mass boundaries in existing regulations</td>
</tr>
<tr>
<td>CAA</td>
<td>Arbitrary/empirically derived</td>
</tr>
<tr>
<td>FAA\textsuperscript{771}</td>
<td>Adoption of mass boundaries in existing regulations (proposed)</td>
</tr>
<tr>
<td>AIAA</td>
<td>Arbitrary/empirically derived</td>
</tr>
<tr>
<td>ASTM</td>
<td>Adoption of mass boundaries in existing regulations</td>
</tr>
<tr>
<td>EASA\textsuperscript{772}</td>
<td>Risk-based, based upon UAS data, arbitrary clusters</td>
</tr>
<tr>
<td>Eurocontrol</td>
<td>Arbitrary/empirically derived by visual clusters</td>
</tr>
<tr>
<td>Clothier\textsuperscript{773}</td>
<td>Based on risk analysis and UAS data, data-oriented natural clusters</td>
</tr>
<tr>
<td>Dalamagkidis</td>
<td>Based on risk analysis and UAS data, arbitrary clusters</td>
</tr>
<tr>
<td>Fraser</td>
<td>Based on risk analysis and UAS data, arbitrary clusters</td>
</tr>
<tr>
<td>Weibel</td>
<td>Based on risk analysis and UAS data, arbitrary clusters</td>
</tr>
<tr>
<td>Kaiser</td>
<td>Methods not stated (informal classification)</td>
</tr>
<tr>
<td>Peterson</td>
<td>Adoption of existing rules</td>
</tr>
</tbody>
</table>

\textit{Table 26: Comparison of Class Boundary Selection Methods in Current Approaches}

For present purposes, some general comments can be made. First, there is a high degree of
disparity as to the approaches taken. In many cases (particularly those produced by the

\textsuperscript{766} For the purposes of this section, I have construed risk-based approaches broadly and not in a strict,
technical sense. There are many different approaches that fall under that banner including those that utilise
fatality and accident rate calculations, as well as those that use kinetic energy estimations etc.

\textsuperscript{767} Including both visual observations and algorithmic analyses. See generally Clothier et al, ‘Airworthiness
Certification Framework’, above n 49, 880.

\textsuperscript{768} Such decisions also heavily influence the regulations as whole: Clothier et al, \textit{Definition of Airworthiness
Categories}, above n 3, 4.

\textsuperscript{769} It is difficult to categorise the respective approaches conclusively in this way given the relevant minutiae
each. The above table is intended only to illustrate the variety of possible approaches to the choice of
class boundaries.

\textsuperscript{770} According to the approach in \textit{CASR Part 101}.

\textsuperscript{771} According to the approach outlined in the \textit{FAA NPRM}, above n 147.

\textsuperscript{772} According to the approach outlined in the \textit{EASA A-NPA}, above n 169.

\textsuperscript{773} According to the approach outlined in Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3.
regulators) the specifics are not properly explained. It is clear that the regulators have favoured adopting mass limits found in existing regulations. In particular, weight limits of 25kg, 150kg and 600kg are relatively common.\textsuperscript{774} However, it is also clear that the proposals developed by those studying the question scientifically and based upon ‘natural’ groupings of UAS according to data have found that other classes may exist which do not align with the commonly accepted weight limits; Fraser and Donnithorne-Tait, for instance, have found that there is little justification for maintaining the common demarcations.\textsuperscript{775} However, it is also notable that in some cases, although efforts are made to use mathematical methods to observe natural classes, on occasion mathematical results are subjected to a ‘rounding’ process to the nearest appropriate figure or whole number. This simple action may in fact detract from the merits of the proposal where not properly justified.\textsuperscript{776}

A related question is that of the optimal number of classes to be used in classifying. Again, there is quite a variance evident in the proposals reviewed. CASA, for instance, utilises 3 classes to cover the full spectrum of mass. Eurocontrol/IABG proposes 4, and EASA and Fraser and Donnithorne-Tait propose 5. Dalamagkidis, Valavanis and Piegl and Weibel and Hansman propose 6.\textsuperscript{777} Some studies, such as the \textit{sUAS ARC Report} emphasise the need for a large number of classes, in particular at the lower end of the weight spectrum. In that regard, it proposed 4 classes of UAS \textit{below} 25kg.\textsuperscript{778} In that regard, it is notable that the UVS International classification scheme utilises 17 classes.\textsuperscript{779} These observations align with those of the AAIF and Clothier et al to the effect that greater ‘resolution’ is required,\textsuperscript{780} particularly for small UAS-AC; that is, regulations must recognise the extreme diversity evident in smaller systems and classify with these differences in mind. This may

\textsuperscript{774} See the approaches of CASA, CAA, FAA, ASTM, and TC.

\textsuperscript{775} Fraser and Donnithorne-Tait, above n 211, 158, 160.

\textsuperscript{776} See for instance the adherence to mass for the purposes of creating classes of UAS in Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111; Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50. Note the significant effect of a change in methodology between the two classifications proposed (as noted above) in Chapter V.

\textsuperscript{777} Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111, 324; Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50, 515; Weibel and Hansman, above n 47, 41.

\textsuperscript{778} \textit{sUAS ARC Report}, above n 521, 22. The proposed ‘LTA Only’ class is not included.

\textsuperscript{779} See Chapter II.A.2.

involves a greater number of classes in order to address the particularly diverse group of small UAS. Ultimately, this is a decision that is likely to be made by reference to a trade-off between ensuring the accuracy of the scheme on the hand, and ensuring that the scheme doesn’t become overly complicated by a high number of classes, on the other. Again, these are not trade-offs that have been studied closely and may not be capable of mathematical resolution.  

**Class Designations**

In a 2008 edition of industry publication *Unmanned Vehicles*, its editor Darren Lake commented that regulators and industry ‘continue to speak vastly different languages and the barrier between them remains the single most difficult challenge when it comes to integrating manned and unmanned flight’. This is particularly so given the imperative for consensus standards, and the application of public consultation procedures to rule development.

Current terminology can generally be summarised as belonging to two groups – those describing UAS by size and weight, and those referring to mission capabilities (being similar terms to those used by military operators of UAS). It should be noted that the nature of UAS operation and development has resulted in an industrial lexicon that is clearly influenced by the military dialect. There is little consistency in the use of terms amongst the UAS industry.

For instance, the terms ‘micro’, ‘mini’, ‘light’, ‘small’ and ‘large’ occur with relative frequency across the schemes surveyed. However, there is a distinct lack of consistency apparent in the way these words are used, as set out in the table below.

---

781 Clothier et al, *Definition of Airworthiness Categories*, above n 3, 9. Of interest here is the consistency with the comments of Fearnley, relating to the choice of the ‘best’ McLarens (as quoted in the preamble): See Fearnley, above n 1. It may be inevitable that an element of subjectivity will affect the decision, though mathematics and statistics can provide useful information.


783 See Vacek, above n 185, 21.

784 Note that not all of the current approaches use labels in this way. Some, for instance, in Clothier et al, *Definition of Airworthiness Categories*, above n 3, the authors use numbers to designate classes. Others, such as in the *ConOps Proposal*, above n 171, use descriptive phrases are used.
It is worth noting that rarely are the same terms used the same way in the current approaches. Despite the ambiguity that may arise in a scheme through the use of ambiguous descriptive terms, the importance of the terminology used to describe UAS is often overlooked and has not been closely studied.

A further issue is that military terminologies (such as those described in Chapter II above) continue to pervade the UAS literature. These terms often describe UAS in terms of their operational capabilities, such as endurance and altitude etc. However, these terminologies are not easily applied to UAS in the context of civil regulations, which are directed more to the characteristics or safety aspects of aircraft than their performance or capabilities (for instance, it is difficult to correlate a ‘tactical’ UAS with the purposes of civil regulation). Terms derived from military usage, or based upon operational characteristics, are may be unhelpful in regulating UAS.\(^\text{787}\) This is likely to be an enduring problem in the near future.

**Applicable Rules**

Airworthiness standards or rules must be defined in a manner such that the requirements for certification or approval are known ahead of time (as they are in existing regulation), particularly in light of the need for a ‘gradation’ of UAS regulations, a tailoring of the rules to the different classes.\(^\text{788}\) Without the definition of applicable rules there is no

---

\(^{785}\) Note there is a variation between the class boundaries presented by Dalamagkidis, Valavanis and Piegl in the two schemes reviewed in Chapter IV.D.2; the version contained in Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50, has been utilised here.

\(^{786}\) The UVS International terminology is included by way of comparison to the regulatory and technical approaches.

\(^{787}\) Eurocontrol/IABG Report, above n 488, 21.

\(^{788}\) Plucken, above n 46, 25, 95; Hayhurst et al, Review of Current and Prospective Factors, above n 214, 28.
classification scheme per se (and also no regulation in the true sense) merely a handful of defined classes, the membership to which is immaterial. The drafting and application of rules is an exercise in the development of law. In this instance, without settled classes of UAS, the design of appropriate rules represents a significant challenge. However, bearing in mind that UAS classification ought to resemble conventional arrangements, and having reviewed the current approaches, it appears that certification requirements will contain the following (with possibly numerous permutations):

(1) a class that is more or less exempt from airworthiness requirements;
(2) a class that is subject to minimal airworthiness requirements; and
(3) a class that is subject to strict (and perhaps full) compliance with airworthiness requirements.

Viewed in that light, it is clear that whatever the precise content of the forthcoming regulations, decisions as to the level of certification (and the level of access) will depend to a significant degree on the establishment of classes of UAS, in some form or other. The finer, more technical details will need to be resolved of course, but it is difficult to see how meaningful discussion of those details can take place without having at least some consensus as to the characteristics of the classes of UAS in question. Once classes are established – for instance a mass boundary of <25kg – then precise requirements can be generated or existing requirements vetted against the characteristics of the class.

Notwithstanding the logic of that approach, the nature of a classification scheme is such that the consequences of class membership are critically important. Thus, it is arguable that the creation of classes should occur hand-in-hand with the development of the rules applicable to each and that classes of UAS cannot be developed without reference to the

---

789 Starr, above n 55, 279 citing Goodman, above n 55, 32.
790 See generally Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 880; See also UVS Handbook (2014), 11 (EASA). The assumption that different airworthiness standards and different airspace access will be available to different types of UAS is inherent in many of the approaches reviewed; see the approaches of Dalamagkidis, Valavanis and Piegl, EASA, and ASTM reviewed in Chapter IV, for instance. Clothier et al note for instance that type categories may not be directly connected to airworthiness categories, but rather that a matrix is established whereby the type category and operational category in question determine the ultimate airworthiness standards. In that fashion, a UAS may be certificated ‘in one or more airworthiness categories dependent on the category of operational area over which it is intended to be flown’: Clothier et al, Definition of Airworthiness Categories, above n 3, 3.
791 Palmer and Clothier, above n 36, 7; DeGarmo, above n 42, 2-40, 3-1, 3-2; Maneschijn et al, above n 42, 353; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 5; AIAA, above n 42, iv.
consequences. It is likely therefore that a multidisciplinary,\textsuperscript{792} staged, approach needs to be taken to the design of a classification scheme, given the technical matters and legal uncertainties involved.

\textbf{D The Need for a framework of reference for UAS Classification}

As set out in Chapter IV, the current approaches to classification have originated primarily from technical perspectives such as safety science, engineering and risk management. Naturally, these approaches seek to understand and improve UAS classifications utilising the knowledge and experience existing in the relevant fields. As noted above, there is a definite trend toward the use of mathematic and statistical methods of analysing and producing classification schemes for UAS. Paired with this trend, there is also an apparent increasing focus on a more rigorous assessment of the risks of UAS, and the need for these risks to be reflected in the classification scheme.\textsuperscript{793} This final section of Chapter V addresses the impasse that is preventing the completion of the task and identifies the central limitations of the current approaches.

Naturally, the work in the area has developed through critiques of prior work and suggestions for improvements are based on alternative approaches that are said to produce classifications that are better, fairer or more accurate. Often, these claims lead to the proposal of a new scheme, leading to a proliferation of possibilities and an expanding range of reasoning processes – and yet no clear way to determine whether any particular proposal is ‘better’ than another.\textsuperscript{794} It is apparent from the consideration of the current approaches that this process of development has not resulted in consensus. This was highlighted in NASA’s comprehensive survey of classification proposals in 2013 and 2014: while a useful tool for comparison, the NASA survey did not proceed beyond presenting the approaches and making initial observations and conclusions.\textsuperscript{795} Recalling the conundrum faced by the author Fearnley in choosing the ‘best’ McLaren F1 cars, I

\textsuperscript{792} See DeGarmo, above n 42, 3-1; Huang, above n 249, 7.
\textsuperscript{793} In that regard, see the approaches of AAIF, Clothier et al, Fraser and Donnithorne-Tait, Weibel and Hansman, Dalamagkidis, Valavanis and Piegl, and Hayhurst et al reviewed in Chapter IV.
\textsuperscript{794} See Clothier, above n 53, 17.
\textsuperscript{795} Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8 notes that the nature of the analysis ‘includes high uncertainty, thus is should be used to draw preliminary observations rather than precise conclusions’: at 13.
argue that current approaches to classification lack the appropriate framework of reference necessary to properly frame arguments and evaluate the merits and weaknesses of any given proposal for classification.

1 No consensus as to the desiderata for UAS classification

As set out above, numerous desirable traits or ‘desiderata’ for the classification or regulation of UAS can be observed amongst the current approaches. That is, there are various statements as to the qualities that are sought in terms of forthcoming regulations, including the following:

<table>
<thead>
<tr>
<th>Trait</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Categories to be disjoint/contiguous*</td>
<td>Clothier 798</td>
</tr>
<tr>
<td>Cognisant of costs</td>
<td>AAIF, Clothier 799</td>
</tr>
<tr>
<td>Complete/Continuous coverage</td>
<td>Clothier 800</td>
</tr>
<tr>
<td>Comprehensive</td>
<td>Takahashi 801</td>
</tr>
<tr>
<td>Consistent/Equivalency</td>
<td>AAIF, JAA 802</td>
</tr>
<tr>
<td>Defensible/Justifiable/Verifiable</td>
<td>AAIF, Clothier 803</td>
</tr>
<tr>
<td>Discrete</td>
<td>AAIF, Clothier 804</td>
</tr>
<tr>
<td>Effective/Efficient</td>
<td>AAIF, Clothier 805</td>
</tr>
<tr>
<td>Fair/Equitable</td>
<td>Clothier, Fraser, JAA 806</td>
</tr>
<tr>
<td>Familiar</td>
<td>Peterson 807</td>
</tr>
</tbody>
</table>

796 This is the term used in Gordon, above n 466, 3 which I adopt.
797 The asterisked terms represent desiderata stated expressly for UAS classification, as opposed to regulation more broadly.
801 Takahashi, above n 21, 494.
802 AAIF Report, above n 11, 9; JAA/Eurocontrol Report, above n 59, 12.
806 Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 872; Fraser and Donnithorne-Tait, above n 211, 162; JAA/Eurocontrol Report, above n 59, 12.
807 Peterson, above n 5, 598.
The breadth of the stated desiderata results, in my view, from the lack of consensus as to the approach to be taken in classifying UAS. Several things are notable; first, certain desiderata are in many cases apparently interchangeable or difficult to distinguish from other desiderata – these words are grouped together in the table; second, some words are aimed at the development process (such as ‘mathematically rigorous’) whilst others are...
directed to the *resulting regulations* (such as ‘suitable number of categories’), still others refer to the *use* of the scheme (such as ‘easy to ease’); third, in most cases the terms are used as if they were self-evidently right and therefore there is little explanation to draw upon in understanding how the desiderata might be converted to actual guidance for designing or evaluating a classification scheme.

From review of the stated desiderata there is an apparent lack of focus in work undertaken towards classification: despite the acknowledged importance, classification is often dealt with as a ‘by-product’ of broader regulatory studies being undertaken. Classification should not be treated as ‘as an exogenous variable’. Yet, the topic is not often dealt with squarely, and, therefore, statements of desiderata for classification specifically are rare and, where identifiable, somewhat sporadic in formulation.

2  *Lack of Reference Point by which to Weigh and Evaluate Desiderata*

While each of the desiderata are clearly desirable in a general sense it would be impossible for any single proposal to satisfy such a diverse array of requirements. Furthermore, as it stands, all of the stated desiderata can be considered to be equally desirable as there is no accepted system or guidance for resolving competing considerations. For instance, there is a clear tension between a requirement for ‘flexibility’ and a requirement that the classification be ‘systematic’ or ‘unambiguous’; flexibility may require that the classification be structured to allow exceptions to the ordinary rule but these exceptions create ambiguities for those using the classification such as to confront the general principle that the public ought to know with certainty the rules that govern it. Exceptions may expressly or by implication empower the regulator to use discretion in

---


822 The notable exceptions are found in the work of AAIF and Clothier et al: See AAIF Report, above n 11; Clothier et al, ‘Airworthiness Certification Framework’, above n 49; Clothier, above n 53. Some of the desiderata stated for UAS classification or regulation are implicit. Maddalon et al, *Perspectives on Unmanned Aircraft*, above n 8 notes, for instance, that ‘[c]lassification also supports risk reduction’ (ie – presumably the tie to risk is a positive trait): at 15.

823 See discussion in Chapter VII below regarding the application of the rule of law principles.
assigning UAS to certain classes or in tailoring the rules, which may of course reduce the transparency of the regime. 824

In practical terms, if a classification scheme were structured such that ‘small UAS’ were those with a UAS-AC of ‘approximately’ or ‘typically’ 2kg to 25kg, questions would arise as to whether a UAS-AC of 1.9kg or 25.1kg was a ‘small UAS’ or something else. A definition of ‘small UAS’ that specified a range from 2 to 25kg would be less ambiguous; a definition that specified ‘≥ 2 to < 25kg’ would be, arguably, less ambiguous again as it makes clear that a UAS weighing exactly 2kg would be a ‘small UAS’. These issues sound trivial, but when one considers the increasing number of UAS-AC in this weight range, minor variations can have dramatic effects for those concerned. 825 It is worth noting that these issues arise in practice: the Eurocontrol/IABG classification described above specifies weight classes of ≤ 500 kg (Class 1) and ≥ 501 kg (Class 2) – there is an obvious ambiguity then as to the proper assignment of a UAS-AC with a mass of 500.5kg as there is a 1kg gap between the two classes. 826

There are further examples of tension amongst the above desiderata. A review of the relevant literature reveals a general desire for the classification of UAS to exhibit ‘simplicity’ or be ‘easy to use’. 827 Equally numerous are calls for a classification that is ‘practical’, ‘rational’, and ‘defensible’. 828 These are seemingly derivations of the pursuit of a classification that is ‘logical’ or ‘objective’. 829 As set out above, this pursuit is often characterised by advocacy for specific characteristics, approaches or features; for instance, the stated requirements that classification be ‘risk informed’ 830 or ‘mathematically

824 See discussion in Chapter VII below regarding the application of the rule of law principles.
825 For instance, Fraser and Donnithorne-Tait query the differences, from a certification perspective, of a UAS-AC weighing 140kg and 160kg (compared to the 150kg demarcation): Fraser and Donnithorne-Tait, above n 211, 158. In this vein ‘A clear objective for a reference framework for unmanned aerial vehicles and systems airworthiness requirements, henceforth referred to as the ‘Reference Framework’, is therefore to be appropriately general in detail, yet sufficiently comprehensive in scope to ensure that it can be applied to most present and future unmanned aerial vehicle types and systems’: Maneschijn et al, above n 42, 352.
826 Eurocontrol/IABG Report, above n 488, 22.
829 See for instance the approaches of AAIF, Clothier et al, Dalamagkidis, Valavanis and Piegl, Fraser and Donnithorne-Tait.
830 Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 5, 13.
rigorous', or in claiming that the use of statistics or natural tendency clustering increases the quality of the proposal. Increasing the internal logic of a classification is a sound objective, but the use of mathematical, statistical, or risk-informed means, could entirely eclipse the ‘simplicity’ of the classification scheme or render the scheme opaque (logical as it may be). A further tension exists between a requirement to be ‘consistent’ or ‘long term’ on the one hand, and ‘flexible’ on the other.

Similarly the desire for ‘objectivity’ seems prima facie unobjectionable but the meaning of the term is not properly explained despite its repetition in the literature. It appears that the term refers to a requirement for ‘impartiality’ – an approach that is ‘independent of any single stakeholder’s preferences’. Mathematical and statistical means are proffered as solutions, but of course there are many possible approaches, and there is no identified ‘higher authority’ to appeal to in order to discern validity or weigh one consideration against another. These issues need to be addressed if effective law is to result.

3 The Properties of Effective Regulation

The work of Clothier et al and NASA provide the most developed consideration of the above issues. In Clothier et al’s search for an ‘effective’ certification framework for UAS, he notes: ‘This leads to the question as to what are the properties of an effective regulation?’ That question is relevant, rightly asked, and recognises the nexus between

---

831 Fraser and Donnithorne-Tait, above n 211, 157.
832 See generally Peterson, above n 5, 598.
833 See AAIF Report, above n 11, 11; Clothier, 877, Clothier et al, Definition of Airworthiness Categories, above n 3, 2, 3, 6, 7, 9; Clothier, above n 53, 4, Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1000; Fraser and Donnithorne-Tait, above n 211, 157, 158.
835 In that regard I note the following aspect of legal approaches and the concept of objectivity: ‘Lawyers and judges like to think that they are objective but as Lord Scarman, a distinguished English judge, once said: ‘Law is not concerned with truth. It is concerned with justice.” Lawyers and judges are not scientists. They are not concerned with absolute truth, assuming there is such a thing. They are concerned with relative truth.’ John Farrar, Legal Reasoning (Lawbook, 2010), 87. In relation to legal reasoning by resort to general principle and analogy in the context of aviation law, see See Elmar M Giemulla ‘The Sources and the Structure of International Aviation Law’ in Elmar M Giemulla and Ludwig Weber (eds), International and EU Aviation Law: Selected Issues (Kluwer Law International, 2011) 63, 74 (‘Sources and Structure’).
836 Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 872. As Fearnley noted in relation to the search for best of the McLarens (quoted in the pre-amble to this work) – objectivity is elusive, and as will be seen below, it is only one of several possible ingredients in ‘effective’ regulation; Fearnley, above n 1.
classification and the regulatory task at hand. Clothier’s analysis draws on 6 ‘guiding principles’ in answering that question; namely, that an effective framework for UAS would be ‘justifiable’, ‘flexible’, ‘systematic’, ‘objective’, ‘practicable’ and ‘cognisant of the costs’ (to paraphrase). Noting the tension between those objectives, Clothier concludes:

Solving such a multi-objective problem is the outcome of a risk-management process. According to internationally accepted standards… the implementation of the risk-management framework encompasses processes for the identification, assessment, evaluation, mitigation, communication and monitoring of a hazardous activity or technology. All components of the risk-management activity are relevant to the development of regulations for UAS; however, of specific interest in this paper are risk matrices, a tool widely used to evaluate risk.

It is apparent that Clothier’s approach conceives the task as a ‘risk management’ issue, thus (naturally) approaching the task using the knowledge and tools available within that technical field. Similarly, NASA’s work identifies that classifying UAS encounters the need for ‘clarity, agreement, and enforceability’ all of which are ‘characteristics important to a useable classification scheme’. The authors there cite the difficulties in reaching objective conclusions as to what these characteristics require, noting the need for more research to develop a ‘sound, scientifically informed decision’. These sentiments echo those within the other approaches reviewed in Chapter IV – the task of classifying UAS is generally seen as a technical or scientific issue, even by those approaches emanating within the regulatory and legal fields (as is discussed in the next section).

---

837 Classification is innately part of the consideration in Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 877 and in Clothier et al, Definition of Airworthiness Categories, above n 3, 4. Classification, specifically, has been the subject of more direct study too: see Palmer and Clothier, above n 36.
838 Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 872; Note that in other work, for instance Clothier, above n 53, Clothier defines the principles as ‘contiguous, complete, sufficient resolution, practicable, justifiable, transparent, objective’.
840 Maddalon et al, Considerations of Unmanned Aircraft, above n 49, 14.
841 Ibid 16.
VI UAS CLASSIFICATION FROM A LEGAL PERSPECTIVE

It is notable that despite DeGarmo’s findings in 2004 that UAS classification involved an area of high legal complexity,\(^{842}\) there has been only limited consideration of the issue from a legal perspective in the intervening decade. The determination of real similarities and differences between UAS for the purposes of airworthiness certification is an important question of law:\(^{843}\)

[L]egislative classes do not exist in nature ready made with clear-cut edges, and the main problems are the formulation of suitable class characteristics and the identification of a member of the class.\(^ {844}\)

The difficulties in formulating an appropriate classification scheme arise because the laws of a society do not operate in a vacuum. Where the classification exists as part of a regulatory action relating to UAS, the law must take account of technical work within a specialised area of economic activity. Like most lawmaking endeavours, UAS regulation is a multidisciplinary concern that involves technical,\(^ {845}\) economic, political and other interests framed against the legal backdrop provided by the relevant legislation: safety becomes a question of law once it involves public participation ‘under government control’.\(^ {846}\)

This Chapter identifies the limited legal consideration of UAS classification to date in order to juxtapose the limitation against the unique conceptual perspective to classification that is provided by legal reasoning. Put another way, this Chapter seeks to highlight the extent of the limitations amongst the current field of work that is created by the lack of legal consideration, and then to illustrate the benefits that such consideration may bring to the regulatory agenda. The juxtaposition therefore marks a point of departure in this thesis from analysing the current (largely technical) approaches to UAS classification, to proactively formulating the basis for the application of a legal perspective. This requires the convergence of the legal and the technical perspectives, given the multi-disciplinary

\(^{842}\) DeGarmo, above n 42, 2-41.
\(^{843}\) See Truax v Corrigan, 257 US 312, (Ariz, 1921), 337-338.
\(^{844}\) Farrar above n 835, 138.
\(^{845}\) See DeGarmo, above n 42, 3-1. See Huang, above n 249, 7.
\(^{846}\) See especially Huang, above n 249, 7. See generally Zhao, above n 821, 187, 194.
nature of the question. The Chapter concludes by illustrating through the work of Brennan and Starr (discussed above) that the core aspects of classification are transferrable between disciplines, though the question of the effectiveness of any specific classification scheme remains dependent upon the specific context. It is therefore central to this Chapter to explain the unique characteristics of the legal context, as distinct from the technical.

A  UAS Classification in Context: A Multidisciplinary Issue

The starting point, and the purpose of this short section, is to acknowledge the multidisciplinary nature of classification undertaken for regulatory purposes, and secondly to emphasise the importance of the legal components of the tasks. Indeed, the concept of classification is not unique to UAS regulation or to the law generally. Rather, classifications permeate society on all fronts. Inevitably, as a form of social governance, regulations of all types and across all sectors encounter and use classification techniques: ‘all institutions require classification of some sort’. 847 This is a result of ordinary human cognition and interaction by which it is thought that human beings must classify the world around them in order to process large volumes of information. 848 A similar logic occurs at a broader social level in terms of governance through the use of official classifications: 849

States have no choice but to categorize. Every state must draw lines between kinds of people and types of events when it formulates its criminal and civil laws, levies taxies, allocates benefits, regulates economic transactions, collects statistics, and sets rules for the design of insurance rates and formal selection criteria for jobs, contracts and university admissions. 850

It can be observed in the examples of official classifications cited in the preceding passage that there are a legal aspects, and non-legal aspects (such as economic, technical, and social aspects) that might well be studied in other fields. However, where a state encodes its classifications within law, these decisions can be studied through a legal prism:

847 Brennan, above n 470, 220.
849 Chen and Hanson, above n 848, 1125.
850 Starr, above n 55, 264.
First, laws work by creating groups and by assigning consequences to being placed in particular groups. Laws apply to categories of events and to classes of people. They make one rule for optometrists and another for oculists, one subsidy for raspberry growers and another for the artichoke industry… Second, groups come to law. Law makes groups, but it also responds to groups. As legislatures are lobbied by groups of constituents… so opportunities arise to advance common interests by lawsuit, and every sort of economic, geographic, and social group sues and is heard.\footnote{Ibid 289, citing Liebman, L, ‘Anti-Discrimination Law: Groups and the Modern State’ in Glazer, Nathan and Ken Young Ethnic Pluralism and Public Policy: Achieving Equality in the United States and Britain (Lexington Books, 1983) 11.}

Thus laws provide a focal point and a means of communication between stakeholders, a point of reference within which a ‘discursive process’ may occur.\footnote{Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 10.} In that sense ‘[l]aw is not simply a passive embodiment of the goals of a particular society’; rather, it is a ‘two way’ process whereby laws respond to society, and society responds to laws.\footnote{Farrar, above n 835, 216; Starr, above n 55, 264; See also Zhao, above n 821, 194.} Thus, the ‘discursive process’ may well occur through other fields,\footnote{Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 10.} such as it has in relation to the debate amongst the technical sources as to the most appropriate UAS regulation. This discourse will influence the development of law, and in reverse, legal considerations naturally frame the debate given that the regulatory action is a lawmaking activity. To that end, as noted above, unique processes and practices have developed within the law which guide the creation of new laws, as well as the interpretation and amendment of existing laws. These practices are discussed further in Chapter VII. Before proceeding to that discussion, the limited legal consideration of UAS classification must be identified and contrasted with the unique characteristics that such legal consideration might bring to the UAS classification issue in order to illustrate the limitations of the technical approaches.

### B Limited Consideration of Legal Context in Current Approaches to UAS Classification

Having acknowledged the multidisciplinary nature of the classification issue, two conclusions can be drawn from the review of the current approaches: first, there are few legal sources that consider UAS classification; second, those legal sources that do...
consider classification, do not consider the issue strictly as a legal issue. These points are discussed in the next two sections.

1 Limited Substantive Consideration by Legal Sources

I have noted above that in 2004 DeGarmo identified classification as a legal issue of high complexity. Notwithstanding that conclusion, few legal approaches to classification exist. The foundational assessments by Peterson and Kaiser in 2006 recognise (respectively) that the classification of UAS is ‘the first issue’ to be addressed in regulation, and that ‘any assessment of the economic and regulatory implications of UAVs needs to consider the specifics of the category of the air vehicle’. Kaiser’s further work on UAS in 2011 reinforced the linkage between the classification and certification of UAS, but confirmed it remained the case that ‘there [were] no internationally agreed definitions for the various (weight) classes of UAVs’ at the time of writing. Plucken’s work that same year examined the similarities and differences between the certification approaches adopted by ICAO, Canada and the US and concluded that ‘the legal classification of UAS is a very difficult and controversial issue’. Plucken’s useful work expressly only ‘touched on’ the issue without analysing the role of classification in detail. In doing so, Plucken noted the ‘relatively small number of up to date legal examinations of UAS regulations’.

The learned aviation law author Diederiks-Verschoor agreed in her 9th edition of ‘An Introduction to Air Law’ that the question of classification was intertwined with that of safety regulation:

---

855 DeGarmo, above n 42, 2-41.
856 Peterson, above n 5, 594. Note that Peterson’s consideration was directed towards operational rules, rather than airworthiness standards.
857 Kaiser, ‘Legal Aspects of UAVs’, above n 83, 345. See also Kaiser, ‘UAVs and Their Integration’, above n 46, 165; Cf Peterson, above n 5, 596.
858 Kaiser, ‘UAVs and Their Integration’, above n 46, 166 n 10.
859 Plucken, above n 46, 26.
860 Ibid.
861 Ibid 5.
862 Diederiks-Verschoor, above n 219.
Thus UAS operations must be as safe as manned aircraft insofar as they must not present or create a greater hazard to persons, property or vessels whilst in the air or on the ground that that attributable to the operation of manned aircraft of equivalent class or category…It is recognised therefore that the need exists to develop a system of UAS classification and appropriate regulation. 863

The remaining legal sources considered do not positively address classification in their studies of the regulatory environment, rather noting the issue indirectly in the course of describing the technology the subject of study: for instance ‘[t]he broad category of unmanned aircraft includes a diverse collection of fixed wing, rotorcraft, and lighter-than-air flying machines, available in a wide variety of sizes and capabilities.’ 864 This a good example of statements of this kind amongst the remaining legal sources reviewed in this thesis. 865 In my view, the necessity to describe UAS in terms of different categories and types in the course of academic work, is the same necessity that drives the need to define a classification scheme for UAS in the course of drafting formal regulations – there is no other way to logically deal with the diversity. 866

This observation goes hand in hand with the conclusions reached by the technical sources. In light of the conclusion of the recent and comprehensive overview of NASA’s technical perspectives on UAS classification reaching a conclusion similar to that expressed by Plucken (namely that it is a complex area requiring closer study), 867 I argue that a legal perspective can provide authoritative and useful guidance that can assist in overcoming the present impasse.

2 No Detailed Analysis of Classification from a Legal Perspective

The consequence of the lack of contribution by legal sources amongst the current approaches to classification outlined above is that little information is available information as to the functioning of a UAS classification in a formal regulatory sense; that is, there is no information as to the operation or design of UAS classification schemes

863 Ibid 263 (citations omitted).
864 Marshall, above n 222, 695
865 See Bellows, above n 14, 611; Gogarty and Hagger, above n 220, 86-89; Kapnik, above n 127, 442 to 444; Michaelides-Mateou and Erotokritou, above n 27, 121-123; Takahashi, above n 21, 513-514, Vacek, above n 185, 22.
866 Starr notes the connection between classification and communication: See Starr, above n 55, 270.
867 Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 16
encoded in written law. Put another way, while the current approaches to classification perceive the task as being one in which a ‘scientific’ classification is in issue,\(^868\) ‘official’ classifications are different and distinct:

Classifications have consequences. Some cause damage, some advantage. That is above all other reasons why people fight over them. Official categories carry particularly serious consequences.\(^869\)

This is not surprising; as noted earlier in this Chapter the concept of regulation is one that encapsulates numerous areas of social activity: economic, legal, political, social, political (to name a few).\(^870\) Technical analyses therefore have their place in any discussion concerning the regulation of UAS, and the classification of UAS for the same reasons. However, as Huang notes, ‘safety in civil aviation is not a purely technical matter; it involves a complex lawmaking process for determining and managing acceptable risks’.\(^871\)

Further, there is a prima facie reason for separately considering classification to be a legal issue, being that ultimately a classification for regulatory purposes will be enshrined in written law,\(^872\) most likely within delegated legislation such as the CASR. That being the case, whatever the specific social, political, technical, economic and social issues relating to UAS might be, ultimately, the development of a classification scheme for UAS certification occurs at least in part within the legal sphere.\(^873\) Put simply, such classification schemes are laws. There is limited recognition of this issue amongst the existing approaches.\(^874\)

The lack of available legal analysis of UAS classification means that the legal aspects to the problem have not yet been comprehensively studied. Consequently, there is limited

---

\(^{868}\) Although certain work displays an appreciation that the classification is occurring for regulatory or legal purposes (see for instance the work reviewed in Chapter V.D.3 above), many approaches reflect scientific classification in the sense of data gathering, clustering and algorithm analysis and the use of statistical means. These of course have a place in the regulatory domain, but without legal input may have reduced effectiveness.

\(^{869}\) Starr, above n 55, 274


\(^{871}\) Huang, above n 249, 21

\(^{872}\) Starr, above n 55, 270

\(^{873}\) See DeGarmo, above n 42, 2-41.

\(^{874}\) See above n 868; See eg Maddalon et al, Considerations of Unmanned Aircraft, above n 49, 2.
appreciation that legal classifications differ from scientific and everyday classifications, and further that different objectives and methodologies apply in law. Furthermore, the numerous legal tools available to develop and evaluate laws have not been applied to UAS classification. These issues are taken up herein.

C Legal Classifications are Unique

Generally speaking, classification (of whatever kind) involves emphasising some differences between things and ignoring other differences so as to abstract for the ‘full complexity of the situation’ only selected traits. In that sense ‘except for its specialized vocabulary, legal analysis looks a lot like other kinds of analysis’. As a form of communication, classification schemes (of all types) are predicated on generalising the world around us, with the result that a significant amount of information is sacrificed in order to reduce the complexity of the perceived world. This trade-off between particularity and generality is inherent in the drafting of laws, too:

They [lawmakers] try to leave nothing confused, to anticipate evasions, to resolve all doubts – yet they know that they can never completely succeed. They will often define the key words at the beginning of the Act, but no definition can be exclusive nor perfectly describe a class of people, things or acts.

However, although classificatory processes may be similar, legal classifications are unique and distinct from other kinds in important ways. Laws have ‘coercive’ and authoritative

---

875 See Starr, above n 55, 271-274.
876 Ibid 268.
878 ‘The world is rife with particularity; only by ignoring most of the countless differences among objects and events are language and understanding possible. Human beings could not cope with their environment, much less communicate, if they did not group sets of discriminable stimuli as equivalent.’: Starr, above n 55, 268. See, similarly, ‘The world is full of single cases: single individuals of animal or plant species, single case histories of disease, single books, rocks, or industrial concerns. By grouping individual objects into a taxon the description of the taxon subsumes the individual descriptions of the objects contained within it’:
879 Sokal, above n 43, 1116. See also, Chen and Hanson, above n 848, 1128.
879 Farrar, above n 835, 2, 89, 95.
879 Ibid 95.
880 Louis Waller, David Derham and Francis Maher, Derham, Maher and Waller, an Introduction to Law (LBC Information Services, 8th ed, 2000), 141; See also Pearce, 2, 19; Farrar, above n 835, 89, 137.
consequences – positive and negative.\textsuperscript{881} A useful explanation is provided by Minow in the text \textit{Making All the Difference: Inclusion, Exclusion, and American Law},\textsuperscript{882} which considers the way in which legal systems differentiate according to race, gender and other social factors:

When we identify one thing as like the others, we are not merely classifying the world; we are investing particular classifications with consequences and positioning ourselves in relation to those meanings. When we identify one thing as unlike the others, we are dividing the world; we use our language to exclude to distinguish – to discriminate… when we simplify and sort, we focus on some traits rather than others, and we assign consequences to the presence and absence of the traits we make significant.\textsuperscript{883}

In light of the consequences, legal classifications must be subjected to close scrutiny and different analytical considerations apply than with respect to folk and scientific classification.\textsuperscript{884} For instance, the creation of a classification of aircraft for the purposes of an engineering study may differ significantly from one produced for the purposes of defining rights and obligations; an engineering approach will also use a different methodology. The primary difference is that in scientific classification, the natural world objects being classified cannot complain for they have no rights or obligations at stake; however, ‘[w]hen institutions classify… they often confront the self-conceptions of the subjects’;\textsuperscript{885} that is, official classifications invest certain decisions with consequences. As set out in earlier in this Chapter, a secondary effect is that, while social and political discourse can affect the creation of laws and the classes they contain, groups affected by classifications will also adjust and arrange around the classification scheme created. By that means, a legal classification of UAS will alter the industry as groups seek to obtain the benefits associated with one class or another.\textsuperscript{886} Therefore, the question of the

\textsuperscript{881} Starr, above n 55, 270.
\textsuperscript{882} Minow, above n 877.
\textsuperscript{883} Ibid 3.
\textsuperscript{884} Starr, above n 55, 266.
\textsuperscript{885} Starr, above n 55, 269.
\textsuperscript{886} Farrar, above n 835, 216; Starr, above n 55, 264.
‘rightness of categories’ – whether a classification scheme creates ‘valid’ distinctions is one which

in the law and public administration is quite different from rightness of categories in science. It is no business of the scientist to worry about the incentive effects of any particular classificatory scheme; the lawmaker must be concerned. The biologist is free to observe the complex phases of birth and death; the legal system must draw boundaries, even if somewhat arbitrarily.

Thus, the differing perspective of a legal approach will reflect in both the overall objectives and in the methodology applied; these considerations will affect the decisions made in relation to classification at every level, such as the ‘drawing’ of boundaries. It is therefore intrinsic to a legal approach that the lawmaking process involves recognition of the utility of classification, on the one hand, but also exhibits the ‘worry’ referred to above in terms of the possible dangers, on the other.

Lawyers encounter the classification of different acts, facts, and things every day; classification is an essential part of a lawyer’s business. Indeed, as Farrar explains in his text on legal reasoning: ‘Lawyers experience the need to classify and the benefits of ordering at least as much as any other group of people concerned with rules.’

Classifications are useful to lawyers, in terms of both learning and communicating legal concepts, leading to an ingrained process of reasoning in terms of established categories which occurs in the teaching, learning and understanding of law. But with the utility comes the danger of ‘blinkered thinking’ that leads lawyers (and others) to ‘rigidly apply’

---

889 Chen notes that classifications can be both ‘helpful and harmful’: Chen and Hanson, above n 848, 1125.
890 Farrar, above n 835.
891 Farrar, above n 835, 54; See also Waller, Derham and Maher, above n 880, 60.
892 See the comments of HLA Hart: ‘If it were not possible to communicate general standards individuals could understand without further direction, as requiring from them certain conduct when occasion arise, nothing that we now recognise as law could exist. Hence the law must predominantly, but by no means exclusively, refer to classes of person, and to classes of acts, things and circumstances; and its successful operation over vast areas of social life depends on a widely diffused capacity to recognise particular acts, things and circumstances as instances of the general classifications which the law makes’; HLA Hart, Concept of Law, 124 cited in William Twining and David Miers, How to Do Things With Rules (Cambridge University Press, 5th ed, 2010), 166.
893 Farrar, above n 835, 54.
particular categories.\textsuperscript{894} Additionally, the classifications may in a sense become proxies for the actual law itself, and some of the finer details omitted from analysis.\textsuperscript{895} It is this aspect of classification that is of particular interest and concern – the tendency for classification schemes to obscure relevant information, obscure their purposes or their effects, or diverge from their stated or actual purposes. In that regard, Professor Kent Greenawalt’s text on the relationship between law and objectivity notes that:\textsuperscript{896}

what is objected to as unfair or arbitrary is when the law’s unfavourable treatment of a group has no relationship to a proper purpose of the legal classification.\textsuperscript{897}

This final point needs to be emphasised as a point of distinction: recalling the comments of Chief Justice Taft concerning the need for classification to reflect ‘real differences and similarities’,\textsuperscript{898} legal approaches ought to be concerned to ensure proper connections between the purposes of the classification, the decisions made in its creation, and the practical effects. In that regard, legal approaches are concerned with questions of authority, rather than scientific, risk management or statistical methods and objectives. As laws are, inevitably, political instruments and therefore subject to political and personal agenda,\textsuperscript{899} all decisions in relation to the design, drafting, and use of an official classification scheme must be vetted against the relevant legal requirements. Legal processes and modern regulatory practices have been designed to ensure as far as possible that decisions of this kind are undertaken in a careful, considered, and appropriate manner.\textsuperscript{900} As the current approaches reviewed derive largely from technical fields, these considerations have not been applied to UAS classification.

\textbf{D Applying a Legal Perspective to the Current Approaches}

The centrality of the notions of purpose and legal authority in relation to official classifications has been noted above. However, as lawyers are naturally concerned with

\begin{flushleft}
\textsuperscript{894} Ibid.\\
\textsuperscript{895} Ibid.\\
\textsuperscript{896} Kent Greenawalt, \textit{Law and Objectivity} (Oxford University Press, 1992).\\
\textsuperscript{897} Ibid 1.\\
\textsuperscript{898} See \textit{Truax v Corrigan}, 257 US 312, (Ariz, 1921), 337-338 (Per Taft CJ).\\
\textsuperscript{899} Starr, above n 55, 264, Farrar, above n 835, 8, 216, 264, 267.\\
\textsuperscript{900} See Chapter VII.A.
\end{flushleft}
the making and assessment of law (rather than the making and assessment of classification schemes per se) there is little practical guidance available as to how the analysis of the current approaches to UAS classification ought to proceed given they (primarily) do not originate in the legal sphere, and are not presented in familiar ways.

It is therefore useful to seek a practical method of explaining and understanding the technical approaches to classification discussed in Chapter IV through a legal lens.901 Furthermore, by force of logic it is necessary to determine a ‘point of departure’,902 some common or core elements against which to measure difference between the current proposals. Without that it would be impossible to compare, in any methodical manner, the UAS regulations produced by CASA against those proposed by the FAA.903

Useful guidance can be obtained from the work of scholars in the related fields of criminology and sociology, and particularly the work of Brennan (a criminologist) and Starr (a sociologist), whose studies of classification have been mentioned earlier in this thesis. These studies deal more with classification as it might be understood in a scientific sense.904 As such, they represent a practical interface for accessing the topic of UAS classification in respect of which the majority of materials are of a heavily technical nature, as noted above, and which favour the use of approaches to classification that more readily correspond to traditional scientific methods.

As a starting point, Brennan notes the connection between the core aspects of classification, and the purposes at hand in designing a classification:

901 This approach is consistent with an understanding of ‘regulation’ that explains the concept as being one in which a broad set of considerations are at play but framed by a legal foundation. Anthony Ogus, Regulation: Legal Form and Economic Theory (Oxford University Press, 1994) 1 explains regulation ‘by reference to different systems of economic organization and the legal forms which maintain them’.
903 NASA’s approach is similar in so far as it considers ‘classification bases’ or ‘factors’ as a point of commonality amongst the current approaches: See, eg Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 13.
904 In fact, presciently, Brennan comments that ‘[m]any commentators have complained about the mass of disconnected typologies’ and that the preponderance of class names has ‘yielded confusion rather than clarity’ leading to ‘much name changing over the years’: Brennan, above n 470, 202, 208. This indeed sounds very familiar for those studying the classification of UAS.
Different kinds of classification are suitable for different purposes, and different classification structures are produced by different measures. Thus the methods, purposes, and structures of classifications are closely interrelated.\textsuperscript{905}

The notion of underlying purpose is also apparent in Starr’s analysis, in which he distinguishes official categories from folk and scientific varieties, offers guidance as to the means by which official (legal) classification schemes might be analysed:

Understanding official social classification requires an analysis that takes into account historical context, collective action and political choice. Historical context is essential because we never start out with a bare slate... At any given time, the legal and other official categories are like geological deposits, with layers of varying age, bearing traces from their period of formation.\textsuperscript{906}

Starr notes that for legal classifications these ‘deposits’ are likely to change according to changes in the background social exchanges that underpin the law and its creation.\textsuperscript{907}

These observations regarding the importance of analysing the legal context of a classification tie in well with those of Minow, Farrar and Greenawalt (discussed earlier in this Chapter), and provide a sound basis upon which to proceed.

In Chapter V I utilised Brennan’s explanation of the purposes, methods and structures that form the background considerations for commencing development of classification.\textsuperscript{908} I then utilised Starr’s explanation of the key ‘preferments’ or decisions that need to be made when reducing a classification scheme to writing as law.\textsuperscript{909} This shows that the current approaches to classification can be understood and assessed against legal authority and opinion, notwithstanding that the current approaches are derived from non-legal (technical) perspectives. This is important given the argument of this thesis that the design and evaluation of a UAS classification scheme is susceptible to legal guidance.

Understanding UAS classification in terms of the core aspects has an enabling effect for the purposes of legal study. In fact, these matters can be restated in terms that are familiar to lawyers concerned with the drafting of legal rules. Indeed, classification schemes can be

\textsuperscript{905} Brennan, above n 470, 202.
\textsuperscript{906} Starr, above n 55, 265.
\textsuperscript{907} Ibid.
\textsuperscript{908} See Chapter V.
\textsuperscript{909} See Chapter V.
understood as a system constructed of rules. As a concept, a rule may take the familiar and simple form that says in certain conditions, a certain right or obligation (or other result) shall attach. That is, for a given event or occurrence falling within the definition of X, then a known and stated outcome Y shall result:

For our purposes any rule, however expressed, or even if it has not been expressed, can be analysed and restated as a compound condition statement of the form ‘If X, then Y’. The first part, ‘if X’, which is known as the protasis, describes a type of situation – it indicates the scope of the rule by designating the conditions under which the rule applies. The second part, ‘then Y’, known as the apodosis, is prescriptive – it states whether the type of behaviour governed by the rule is prohibited (‘may not’, ‘ought not’), required (‘ought’ or ‘must’) permitted (‘may’) and so on.910

One can see within this formulation that a classification process is at play. Differences and similarities can be observed primarily in the protasis; the question of whether any particular behaviour, activity or object is an ‘X’ (or not). In formulating a definition of ‘X’, one necessarily defines what is not ‘X’, and hence, what is not subject to the apodosis.

In the formulation of a rule, it is difficult to divorce the protasis from the apodosis. In the statement ‘if X, then Y’, both the X and the Y (the protasis and apodosis) are important. In terms of a classification scheme for UAS (for instance), it might be appropriate to think in the following terms:

If X (for instance, ‘Small UAS’) then Y

If V (for instance, ‘Medium UAS’) then W

If T (for instance, ‘Large UAS’) then U (and so on)…

Each of X, Y, V, W, T, and U must be defined, with X, V and T combined representing the total group of UAS, and Y, W, and U representing the total group of consequences (ie – the body of applicable rules). If we define only X, V, T then we have classes but no classification scheme because there are no consequences to class membership; the

910 Twining and Miers, above n 892, 90.
classification is meaningless. If we define Y, W, and U then we have a set of purely theoretical requirements and no means of ascertaining which UAS they attach to (and again, no classification scheme). The above would represent a relatively standard form of rulemaking, whereby a legal draftsperson would seek to give effect to relevant governmental policies, following a plotted course that included the need for interfacing with industry and the relevant government departments responsible for the rules.

Using these methods of simplifying the complex task of classifying UAS and translating the core aspects into recognisable legal terms provides a basis for completing consideration of UAS classification as an exercise in developing rules. More specifically, an appreciation is gained that the rules in question are not ‘everyday’ or ‘scientific’ rules, just as classification schemes enshrined in law are not ‘everyday’ or ‘scientific’; rather, the rules in question have a legal character. Established procedures have evolved in the practice of law for the design and evaluation of such rules. Chapter VII provides an outline of the guidance that is available to the classification task for UAS when viewed in this way, in order to propose that this guidance can be used to identify a legally-derived framework of reference that can be applied to the task.
VII DEVELOPING A FRAMEWORK OF REFERENCE FOR UAS CLASSIFICATION

Much of the UAS literature speaks about creating a certification regime for UAS as part of broader ‘regulations’ pertaining to UAS. For the purposes of developing a framework of reference, it is necessary to be more specific as to what that actually means. The term ‘regulation’ is susceptible to many meanings. One understands the term as recognising that ‘regulation’ is fundamentally a politico-economic concept and, as such, it can best be understood by reference to different systems of economic organisation and the legal forms which maintain them. Regulation generally involves ‘the intentional use of authority to affect behaviour of a different party according to setting standings, involving instruments of information-gathering and behaviour modification’. As noted above, ‘regulation’ is therefore a multidisciplinary issue. However, it generally takes legal form (of differing kinds).

In aviation law, the ICAO regulatory system functions by creating a two-tier system of primary legislation (giving effect to the requirements of the Chicago Convention in each state at a level of generality) and secondary legislation which deals with the regulatory issues in more detail. In the case of UAS, the relevant certification regime will be established in the form of secondary legislation. The fact that this form of law does not undergo direct parliamentary scrutiny (as with primary law) means that secondary legislation is subjected to a series of ‘checks and balances’ to ensure such laws are properly scrutinised.

In his work (considered further below) Salembier identifies the importance of designing a regulatory system having regard to the regulatory processes that have developed within the law over the course of time. These regulatory processes correlate with the principles

---

911 Ogus, above n 901, 1
912 Baldwin, Cave and Lodge, ‘Introduction: Regulation’, above n 870, [1.4].
914 Ogus, above n 901, 1.
915 Diederiks-Verschoor, above n 219, 257; See Bartsch, above n 259, 452; Maneschijn et al, above n 42, 352.
916 Huang, above n 249, 224.
of the ‘rule of law’, upon which modern regulatory practices are essentially modelled. As Salembier notes, paying close attention to the ‘rule of law’ increases the effectiveness of the resulting rules; that is, adhering to the rule of law assists the rules to attain their statutory objectives. The principles are not concerned with the governmental motives for regulating. Rather, the rule of law provides a means of connecting the policy and expressed objectives of the regulatory action to their ultimate expression in the regulatory system in the form of written law: ‘an effective regulatory system creates rules that attain their objectives’. In other words, these principles are designed to increase the quality of laws by focusing on ensuring authoritative, workable, accessible, stable, and impartial rules. These concepts correlate with the desiderata evident in the current approaches, as set out in Chapter V.D.1. Importantly, the rule of law principles are equally applicable to the development of aviation safety regulations as any other exercise of governmental power. For instance, adherence to the rule of law is necessary to ensure ‘fairness in content and procedure’ and to restrain the arbitrary use of power in aviation regulation:

To remain effective and therefore relevant, the law must be responsive to changes in social behaviour, technological advancements, societal attitudes and mores within its jurisdiction. This is particularly true in rapidly changing, technocentric industries such as aviation where business efficiencies can be impeded if the law cannot readily accommodate the uptake of new technological enhancements within its regulatory regime.

Doubtless, the rule of law applies to the development of a certification regime for UAS, though its application has yet to be considered directly in any legal or technical writing on UAS regulation.

---

921 Ibid 173 (emphasis added).
922 See Chapter V.D for the discussion as to desiderata.
923 Huang, above n 249, 266 notes that ‘a coherent, uniform, and sustainable safety system for international civil aviation must be solidly based on the rule of law’.
924 Bartsch, above n 259, 11.
925 Ibid.
Based on the understanding set out above that classification is an issue in the creation of a certification regime for UAS (which manifests as secondary legislation) key guidance can be obtained by understanding the way that the development of secondary legislation interfaces with the broader regulatory system. This system is described in the next section by reference to Salembier’s work. In Chapter VIII I will then demonstrate the way in which this understanding can be applied in practice to evaluate the quality of an existing UAS classification scheme.

A  The Regulatory System

Earlier in this thesis I identified that the creation of UAS regulations ought to be viewed as a task taking place within a ‘regulatory system’. Salembier’s work on the design of regulation conceives of a ‘regulatory system’ that consists of:

(a)  the ‘regulatory regime’, being the ‘rules of conduct’ created by a government in order to influence some aspect of social activity (presumably towards one end or another); and

(b)  the ‘regulatory process’, being the rules created by a government that govern the creation of other rules, such as regulatory regimes.

Both sets of rules are important, and each influence the shape of the system as a whole and the degree to which the regulatory system can be said to be effective. I shall briefly expand upon these concepts as a means of explaining precisely where in this regulatory the issue of establishing a certification framework for UAS lies, in order to further explain that legal concepts can provide guidance as to how the framework can be developed.

1  The Regulatory Regime

As mentioned above, a regulatory regime generally consists of at least two levels, as with the aviation safety regime. First, a level of primary legislation is prepared and enacted by parliament and which in most cases contains the general requirements or general

927  Ibid.
928  Ibid.
principles sought to be achieved by parliament (for instance to give effect to a treaty).\textsuperscript{929} Frequently, regulatory scenarios involve the need to control economic or technical matters which are beyond the scope of the primary legislation and the expertise of parliament.\textsuperscript{930} Therefore, statutes often provide for the promulgation of a second level of law generated, implemented and monitored by a specialist government agency.\textsuperscript{931} As set out above, this kind of law may be referred to as delegated or subsidiary legislation, but more commonly is simply called ‘regulation’. These laws are not passed by parliament – rather, the regulator has the necessary power to make the law, and this law is then decreed to be effective.\textsuperscript{932} This permits those with the necessary expertise to refine requirements within the broader mandate created under the primary legislation, and enhances a regulator’s ability to respond to changing circumstances promptly without the undergoing the full parliamentary process which inevitably involves delay.\textsuperscript{933} 

2 \textit{The Regulatory Process}

Primary and secondary laws to one side, the regulatory process separately plays an important role in increasing the effectiveness of a legal system. Though it says nothing about the substantive, political objectives sought to be achieved by the regulatory action,\textsuperscript{934} the regulatory process complements the regulatory regime by assisting law-makers to achieve the objectives of the regime. The content of the regulatory process will also differ from nation to nation, but most Western economies have adopted similar approaches as part of a ‘better regulation’ agenda that has been on foot since the 1990s and aims to improve the quality of regulation.\textsuperscript{935} The content and function of the regulatory process can be roughly equated with the principles of the ‘rule of law’ which are broadly applicable across jurisdictions.\textsuperscript{936}

\textsuperscript{929} Ibid 169, 170; See also Farrar, above n 835, 137.
\textsuperscript{930} Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 170.
\textsuperscript{931} Ibid.
\textsuperscript{932} Ibid.
\textsuperscript{933} Ibid.
\textsuperscript{934} Ibid 173.
\textsuperscript{936} Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 17-174; ‘Farrar, above n 835, 258-259, notes that the ‘rule of law still survives as a supra-national concept in the Western world’. 
Salembier calls the rules that comprise the regulatory process ‘meta-rules’. They are ‘rules about rules’. These meta-rules guide how the rules in the regulatory regime are made (or ought to be made). This is critical because the meta-rules guide the creation of secondary legislation. The regulatory process aspects of the system have been subjected to closer scrutiny in recent times, based on a growing understanding that the regulatory process can significantly impact the shape and effectiveness of the regulatory system. Indeed, as Salembier notes:

Any regulatory legislation that delegates rule-making power or confers unfettered discretion on individuals or subordinate bodies can lead to unpredictability and to a reduction in the effectiveness of the regulatory regime. Even the most principled of legislation can give rise to chaos if it ignores the principles of the rule of law. How then can this be avoided or, at the very least, controlled? This is where the second component of the regulatory system comes in, in implementing a system of controls over the types of rules that go into a regulatory regime, and how those rules are promulgated. This requires a set of rules about how regulatory rules are made – a set of meta-rules if you will. These rules constitute the regulatory process. Choosing the proper meta-rules will ensure that the rules that are produced – the regulatory regime – will be effective.

Thus it is that both aspects of the system are important for maintaining the effectiveness of the system; that is, achieving the objectives of the regulatory regime. Again, the precise contents of the regulatory process will vary from place to place. However, I have noted that a degree of harmonisation of these processes has occurred in more recent years as part of the ‘better regulation’ agenda. That agenda reflects the view that:

High quality regulation is both effective in addressing an identified problem and efficient in terms of minimising unnecessary compliance costs imposed on the community. The best regulations achieve their objectives and at the same time deliver the greatest net benefit to the community.

---

938 Salembier, ‘Designing Regulatory Systems - Part II’, above n 919, 1.
939 Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 170, 173-174
940 Ibid.
941 See OECD, above n 935, 1.
As such, modern regulatory practices normally take account of these factors as a part of the regulatory process. The better regulation agenda focuses on the way that regulations are generated. As a result, a series of checks and balances were introduced by the member states of the Office of Economic Cooperation and Development (‘OECD’) (which includes Australia and the other states studied in this thesis) in order to take account of available tools to assist in guiding the shape and nature of regulations. For instance, risk assessment procedures are commonly ‘built-in’ at the developmental stage and may utilise scientific, mathematic, engineering and statistical methods to estimate risks. Such assessments facilitate more ‘objective’ estimations of risk ‘so that different people can take the same data and come up with a similar assessment of the risk’. 943

Risk assessments are often accompanied by ‘cost/benefit’ analyses which seek, in essence, to calculate the net result of the regulatory action in terms of a ‘utilitarian aggregation of individual gains and losses’. 944 In some cases, such as in the Australian model, a ‘calculator’ system is employed in order to assist those involved in the regulatory process to quantify costs and benefits. 945 These are measures implemented to further the goal of OECD determination in 1997 that states ought to conduct a ‘systematic examination of legal provisions in order that they might achieve their objectives more effectively and efficiently’. 946 The regulatory process therefore plays a critical role in ensuring that sufficient ‘pre-enactment review’ occurs before regulations assume legal force. 947

B  Guidance for Classifying UAS Obtained from Understanding Regulatory Nature

This thesis begun by observing that although classification has been recognised as an important element in the broader regulation of UAS and that the current approaches to classification elicit the need for a framework of reference for the classification task.

943 Alan Randall, Risk and Precaution (Oxford University Press, 2011), 43. This is consistent with the notions underpinning the modern aviation system and the prevalence of the precautionary principle.
944 Randall, above n 943, 46.
946 Salembier, ‘Designing Regulatory Systems - Part II’, above n 919, 2.
947 Ibid.
Without that reference point it is difficult to develop general guidelines and impossible to evaluate the pros and cons of any given classification scheme as the criteria for a ‘good’ classification scheme have not been clearly articulated. This lack of accepted criteria for evaluating classification schemes is apparent in the variety of stated desiderata.

Brennan’s work, discussed above, raises a critical question which must be kept in mind in developing a framework of reference for UAS classification: ‘What is a good classification system? One response is, good for what?’ Brennan, above n 470, 214; The work of Clothier raises a similar query as to the reason for undertaking the classification: See Clothier, above n 53, 4.

Again, the question of purpose therefore arises. Accepting that classification is to occur at the level of secondary legislation, one perspective is to ask what is a ‘good’ classification for legal purposes: this may not align precisely with answers given in risk-management, economic, scientific, mathematic or statistical contexts as each field necessarily has its own unique approaches and principles.

Much can be gained through clarifying the core principles that are relevant to classification from a legal perspective. This thesis argues that a framework of reference can be obtained for classifying UAS by asking whether a given classification scheme is ‘good’ or ‘effective’ as a law. What, then, is a good – or effective – law? It may be that the desiderata identified above do accurately reflect traits that are thought to be desirable in all laws; for instance, effectiveness and efficiency are two commonly stated qualities. However, the question needs to be approached systematically, and in accordance with legally acceptable methods, lest the same confusion will arise as can be seen in the current approaches. I accept that in order to determine whether a regulatory system is ‘good, acceptable, or in need of reform it is necessary to be clear about the benchmarks that are relevant to such an evaluation’.

These benchmarks (or at least, cohesive benchmarks) cannot be derived from a review of the current approaches. However, benchmarks can be ascertained through an

---

948 Brennan, above n 470, 214; The work of Clothier raises a similar query as to the reason for undertaking the classification: See Clothier, above n 53, 4.
949 See, eg, Best Practice Regulation Handbook, above n 945, 4;
950 Baldwin, Cave and Lodge, Understanding Regulation, above n 259, 76.
951 There have been only limited attempts to define ‘guiding principles’ relevant to classification: see AAIF Report, above n 11, 8.9; Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 872; Clothier, above n 53, 4.
understanding that the classification exercise occurs within a regulatory system: each component therefore plays a part in ensuring the effectiveness of the system, and therefore each component guides the decisions that need to be made when creating rules.

C  Classification for the Purposes of a Certification Regime

Formal regulations for UAS – in the sense of secondary legislation – will involve developing rules that cover each of the ‘three pillars’ of safety regulation described above. However, the relevance of classification to this thesis can be localised further. In Chapter IV of this thesis, I observed that the current approaches to the classification of UAS arise in the context of an identified need for a ‘certification regime’ or ‘certification framework’ similar in function to Part 21 found in existing regulation. As noted above, Part 21 establishes a general ‘framework’ for the certification of different kinds of conventional aircraft by reference to established types: normal, aerobatic, transport etc.

There are therefore two parts to the task of developing the UAS certification regime; first, defining a general certification regime so as to distinguish the relevant types, and secondly, developing the ‘standards, procedures and recommended practices’ to be tailored to each of these types. The latter do not ordinarily form part of legislation per se but exist in technical documents published by the regulators. This is consistent with the Chicago Convention system in relation to conventional aircraft. What is required, it is said in the current approaches to UAS classification, is a focus initially on establishing airworthiness ‘types’ for UAS (ordinarily to be based on risk studies of the relevant types), before the precise airworthiness requirements for each class are determined.

In that manner, the requirements for each class can be ‘tailored’ to the different types by

952 See Chapter II.
953 See also Chapter III.B in relation to the certification regime for conventional aircraft.
954 AAIF Report, above n 11, 6; See also Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 5.
955 AAIF Report, above n 11, 6.
956 Ibid 6; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 5
957 See Chapter III.
958 Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 5.
959 AAIF Report, above n 11, 7, Clothier et al, Definition of Airworthiness Categories, above n 3, 871, Clothier, above n 53, 6; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 4, 5.
way of a gradation of the rules. As set out above it is difficult to contemplate the precise, technical requirements for the design, manufacture, maintenance and operation of the UAS without reference to broad ‘types’.

This approach correlates with an understanding of the key decisions – the two parts to the certification task have been divided between the creation of classes (criteria, boundaries and names), on the one hand, and the definition of the applicable rules, on the other. Therefore, it is immediately clear that the classification of UAS is inexorably linked with the development of a certification regime for UAS. Critically, the first 3 key decisions can be addressed at the regulation level – that is, by way of subordinate or delegated legislation.

This tiered structure is reflected in the governance system established by the Chicago Convention. In that regard, the nations referred to in this thesis – as signatories to the Chicago Convention – have generally established domestic laws that normally exist in a two-tier structure of primary and secondary legislation. For instance, ICAO stipulates 8 critical elements of the safety system, ‘the first such element being primary legislation and the second a code regulations, that represents the means by which States implement the standards contained in the Annexes to the [Chicago Convention].

In that regard, the relevant jurisdictions have each essentially adopted a similar framework consisting of a ‘primary structure that addresses generic issues, with each element of the primary structure further populated with deeper levels and detailed contents’. In accordance with

---

960 Plucken, above n 46, 95; Palmer and Clothier, above n 36, 2, 7; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 6.
962 See Chapter V: This also resonates with the observed connections between the protasis and apodosis as a rulemaking issue: see Chapter VI.D.
963 This has been recognised most clearly by Maddalon et al, Perspectives on Unmanned Aircraft, above n 8 in stating that classification is ‘foundational to a long-term certification framework’; at 4. See also AAIF Report, above n 11, which noted that the regulatory issues for UAS were ‘intrinsically linked’ with those of classification: at 3.
964 See, eg, Maneschijn et al, above n 42, 352; See also Barstch, 145.
965 Diederiks-Verschoor, above n 219, 257.
966 Maneschijn et al, above n 42, 352.
the *Chicago Convention*, these laws are generally harmonised, though the precise content of the laws from nation to nation does vary.

The upshot is that an understanding of UAS classification as an issue occurring within the creation of secondary legislation, as part of a broader regulatory system, can provide critical guidance or benchmarks in developing and evaluating classification schemes for UAS. Therefore, despite its novelty and challenges, the classification task occurs not as a standalone issue but rather within a recognised legal structure and in a recognised legal form. Given the harmonisation of the laws and the relevant legal structure, this understanding of the regulatory system applicable to UAS has general application. Similarly, the guidance that can be obtained through this understanding can be tailored and used in most *Chicago Convention* States. This next section illustrates precisely how this guidance can be obtained (by reference to Australian laws) through a review firstly of the relevant aspects of the regulatory regime applicable to the development of a certification regime, followed by an explanation of the relevant regulatory process.

D  Guidance Obtained from the Regulatory Regime

As set out above, the creation of a certification regime for UAS is inextricably linked with the question of classification.\(^{967}\) Hence the design of a classification scheme for UAS is primarily a task occurring at the level of secondary legislation, within the general structure of the *Chicago Convention* laws in force from place to place. As an item of secondary legislation, the certification regime for UAS must be consistent with the purpose and intent of the primary legislation, lest any regulations are liable to be declared ultra vires or invalid.\(^ {968}\) Therefore the development of UAS regulation involves questions of both the legislative objectives to be achieved and the process to be followed, being the two limbs of the regulatory system. This section deals with the guidance that can be obtained through examination of the former.

Legal techniques have developed within the study and practice of law in order to interpret the purposes of primary legislation. For instance, the s15AA of the *Acts Interpretation Act*

\(^{967}\) AAIF *Report*, above n 11, 2. See Chapter V.A.

\(^{968}\) Farrar, above n 835, 34.
1901 (Cth) stipulates that in ‘interpreting a provision of an Act, the interpretation that would best achieve the purpose or object of the Act (whether or not that purpose or object is expressly stated in the Act) is to be preferred to each other interpretation’. It is not within the scope of this thesis to undertake a fulsome examination of legal approaches to the interpretation of legislation; it is enough to observe here that it is generally accepted in Australia that a court may have regard to the following matters (but always taking the actual words of the legislation as foremost) in defining the purpose or object of legislation.  

(a) the literal words of the provision in question, including express statements of purpose;  
(b) the pre-amble and long title of the statute;  
(c) explanatory memoranda generated by parliament;  
(d) the terms of any relevant international treaty or convention; and  
(e) other extrinsic materials, including Hansard and certain policy statements.

The information derives from a review of these materials can be used to define the purposes relevant to designing a classification scheme for UAS. The following is an overview of some of the important matters to consider in interpreting Australia’s regulatory regime, which I utilise as an example of the legal regime within which UAS must integrate.

---

969 See Bartsch, above n 259, 61-62.
971 See Pearce, above n 970, 194-195; Bartsch, above n 259, 62-63; See Acts Interpretation Act 1901 (Cth) s 13(2)(a)-(b).
972 See Pearce, above n 970, 92-100, 107-111; Bartsch, above n 259, 62-63; See Acts Interpretation Act 1901 (Cth) s 15AB(2)(e).
973 See Pearce, above n 970, 102-105, 107-111; Bartsch, above n 259, 62-63; See Acts Interpretation Act 1901 (Cth) s 15AB(2)(d).
974 See Pearce, above n 970, 92-100, 105-111; Bartsch, above n 259, 62-63; See, eg. Acts Interpretation Act 1901 (Cth) s 15AB(2)(f).
975 This is not intended to be an exhaustive or comprehensive coverage of a nuanced topic (the topic is too broad for consideration in this thesis), but rather an illustration of the possible utility of a review of legal context.
Australia acceded to the terms of the *Chicago Convention* by the ratification contained within the *Air Navigation Act 1920* (Cth). Australia as a nation is therefore legally bound to implement its terms. The *Aviation Act* gives effect to its terms, and serves as the primary expression of matters relating to aviation safety. Amongst other things, the *Aviation Act* creates CASA and outlines its functions and duties. It also delegates some authority to CASA (via the Governor General) to make regulations that ‘are not inconsistent with the Act’. CASA in turn developed two main sets of regulations – the *Civil Aviation Regulations 1988* (Cth) and the CASRs (already mentioned). Between them, the two sets of regulations define the regime relating to the licensing of aircraft and pilots.

The governing principles of the regulatory regime can be ascertained because they are either expressly stated or can be derived as a matter of statutory interpretation from the *Aviation Act*. For instance, the following principles and objects can be derived from analysis of the *Aviation Act*:

(a) By its long title, the *Aviation Act* is described as being ‘an Act to establish the Civil Aviation Safety Authority with functions relating to civil aviation, in particular the safety of civil aviation, and for related purposes’;

(b) s 3A states that the ‘main object of this Act is to establish a regulatory framework for maintaining, enhancing and promoting the safety of civil aviation, with particular emphasis on preventing aviation accidents and incidents’;

(c) s 9(1)(a) imbues CASA with duties and functions that include relevantly ‘conducting the safety regulation of… civil air operations in Australian territory’;

(d) s 9(1)(e) requires CASA to carry out that function by issuing certificates and licences, with s 9(1) of the *Aviation Act* also directing CASA to:

i. developing and promulgating appropriate, clear and concise aviation safety standards;\(^\text{979}\)

---

\(^{976}\) See *Air Navigation Act 1920* (Cth) s 3A.

\(^{977}\) See *Civil Aviation Act 1988* (Cth) s 98.

\(^{978}\) Rules relating to airspace are governed by other legislation, under the auspices of Airservices Australia, which provides operational aspects of airspace usage such as air traffic control services.

\(^{979}\) *Civil Aviation Act 1988* (Cth) s 9(e).
ii. develop effective enforcement strategies to secure compliance with aviation safety standards;\textsuperscript{980}

iii. conduct comprehensive aviation safety industry surveillance, including by assessing safety-related decisions taken by industry management at all levels for their impact on aviation safety;\textsuperscript{981}

iv. conduct regular reviews of the system of civil aviation safety in order to monitor performance of the aviation industry, to identify safety-related trends and risk factors, and to promote the development and improvement of the system;\textsuperscript{982}

v. conduct regular and timely assessment of international safety developments;\textsuperscript{983}

and

(e) CASA must also carry out its duties and functions in accordance with its international obligations, including the Chicago Convention.\textsuperscript{984}

With respect to the last point, the Chicago Convention has been interpreted and its objectives studied by numerous writers. It is beyond the scope of this thesis to conduct a full analysis; however, it is relevant to mention that the Chicago Convention itself contains a statement of the relevant aims and objectives in art 44 (some 9 statements of objective).\textsuperscript{985} Generally, the Chicago Convention is considered to promote the ‘dual objectives’ of ‘safety and growth of the industry’.\textsuperscript{986} While there is clearly foremost emphasis on the maintenance of safety, it has been noted that ‘a place of prominence’ is

\begin{footnotes}
\item[980] Ibid s 9(d).
\item[981] Ibid s 9(f).
\item[982] Ibid s 9(g).
\item[983] Ibid s 9(h).
\item[984] Ibid ss 11, 98(1)(c).
\item[985] Chicago Convention art 44 dictates that the aims and objectives of ICAO are in effect to ‘(a) Insure the safe and orderly growth of international civil aviation throughout the world; (b) Encourage the arts of aircraft design and operation for peaceful purposes; (c) Encourage the development of airways, airports, and air navigation facilities for international civil aviation; (d) Meet the needs of the peoples of the world for safe, regular, efficient and economical air transport; (e) Prevent economic waste caused by unreasonable competition; (f) Insure that the rights of contracting States are fully respected and that every contracting State has a fair opportunity to operate international airlines; (g) Avoid discrimination between contracting States; (h) Promote safety of flight in international air navigation; (i) Promote generally the development of all aspects of international civil aeronautics. See Ludwig Weber, ‘International Organizations’ in Elmar M Giemulla and Ludwig Weber (eds), International and EU Aviation Law: Selected Issues (Kluwer Law International, 2011) 75, 77-78.
\item[986] Bartsch, above n 259, 107.
\end{footnotes}
also accorded to ‘concepts of… ‘regularity’, ‘efficiency’, ‘economy’ and ‘equality of opportunity’” 987 This is consistent with my observations above in relation to the question of certification that, though safety may be of paramount importance, financial and economic matters must be taken into account at a practical level; that is maximising safety consistent with what is realistic and achievable for the aviation industry at any given point in time.988 It stands to reason, then, that a classification of UAS (as a law) must comply with the same principles of safety, efficiency, growth and harmonisation that flow from the Chicago Convention.989

It is also worthwhile considering the effect of the applicable governmental policy in determining the purposes and intent of Australia’s aviation safety regime.990 The Aviation White Paper covers topics too vast to fully address in this paper, but it suffices to mention that the principle effect of the policy is to:

(a) verify the government’s commitment through CASA to maintaining aviation safety and security;991
(b) encourage growth, innovation and investment through the certainty provided by long-term policy and continued maintenance of safety and security;992
(c) recognise the importance of the aviation industry to Australia’s economy as well as its sensitivity to the global economic environment;993 and
(d) in terms of UAS specifically, ensure that CASA enhances its oversight and capacity to regulate UAS by examining safety trends in the technology.994

988 See Huang, above n 249, 54; See also, Palmer and Clothier, above n 36, 229. With respect to the predominant importance of safety, see Weber, above n 985, 79.
989 There is limited consideration of this point: Clothier notes that ‘UAS safety regulations will need to be tailored to the risk, cost, benefit and technical constraints of different sub-classes of the UAS fleet’: Palmer and Clothier, above n 36, 229. As to harmonisation as an objective, see Plucken, above n 46, 4; De Florio, above n 64, 6 [3.1.1]. Weber, above n 985 notes as well that aviation ‘security’ may be seen as another important objective which may be paired with ‘safety’: at 79-80. The issue of security is not specifically considered in this thesis.
990 Though this is of debatable legal persuasiveness: See eg Pearce, above n 970, 117.
991 Aviation White Paper, above n 31, 2.
992 Ibid 2, 18.
993 Aviation White Paper, above n 31, 30.
Finally, given the *Aviation Act* (via the *Air Navigation Act 1920* (Cth)) and the related regulations give effect to Australia’s international obligations under the *Chicago Convention*, as a matter of interpretation, regard may also be had to the terms of the *Chicago Convention*.995 Using the Australian example, the analysis leads to the general conclusion that assurance of safety of the system is paramount, but that the economic concepts of growth, innovation and investment are important though secondary objectives of the regulatory regime.996 It is also important to note that the adherence to safety and the promotion of growth are expressly to be achieved through the development of safety standards that are ‘appropriate, clear and concise’.997 This reflects an important consideration – that safety can improved through clarity; that is, the drafting of rules directly affects the safety performance of the system.998

E  Guidance Obtained from the Regulatory Process

The point made immediately above – that design considerations can directly affect the degree to which a regulatory system attains its objectives – is an issue that is emphasised in Salembier’s discussion of regulatory process. The function of the regulatory process in the design of a regulatory system presents a critical piece of the puzzle for the prospects of UAS classification.

A preliminary review of the regulatory process elements applicable to the design of Australian aviation regulations, including those for UAS, yields the following possible sources of guidance:

(a) express standards in the preparation and drafting of secondary legislation, as mandated by Commonwealth parliament in the *Legislative Instruments Act 2003*

---

995 Pearce, above n 259, 53-60. See *Acts Interpretation Act 1901* (Cth) s 15AB(2)(d).
996 Importantly, CASA’s purview is limited to ensuring safety, and does not have regard to economic issues by its own account. See above n 330. In practice, these economic issues are still addressed, indirectly, in the creation of airworthiness standards that are based on the ‘practicability’ principle, and the use of other means in the regulatory process: see De Florio, above n 64, 47. Bartsch’s analysis concurs that safety comes first, but that economic considerations are important, secondary factors in aviation policy: See Bartsch, above n 259, 92, 107; Milde, above n 987, 131.
997 *Civil Aviation Act 1988* (Cth), s8.
998 Bartsch, above n 259, 147; Safety has a legal aspect: Huang, above n 249, 7. Clarity is also desirable from an economic perspective: Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 167.
(Cth), which mandate consultation with industry and the improvement of legal effectiveness, clarity intelligibility of secondary legislation to anticipated users;\(^{999}\)

(b) the dictates of the Senate Standing Committee which specifically must scrutinise secondary legislation before it is made to ensure the meaning and operation of the instrument is clear, as well as generally considering the rights and liberties affected by the law and ensuring these are not unduly burdened;\(^{1000}\)

c) assessments required to be undertaken through the Office of Best Practice Regulation (‘OBPR’), which has developed a handbook for government agencies,\(^{1001}\) and which requires the calculation of likely costs and the preparation of RIS involving a close consideration of the risks and benefits involved in the regulatory action using an evidence based approach;\(^{1002}\) and

d) requirements imposed by Australia’s membership in the OECD which has been actively furthering the cause of the ‘better regulation’ agenda for many years (as set out above). The OECD’s requirements are usefully summarised in Figure 2 below, as an example of the kinds of considerations at issue in the regulatory process.\(^{1003}\)

These align broadly with those contained in the OBPR’s guidance material.

\(^{999}\) Legislative Instruments Act 2003 (Cth) s 3(b)–(e).


\(^{1002}\) See The Australian Government Guide to Regulation, above n 1001, 17-20, 31-38, 47; See also Best Practice Regulation Handbook, above n 945, 36.

\(^{1003}\) See Argy and Johnson, above n 942, 6 (from which Figure 2 is drawn).
### OECD Principles of Regulatory Design

- **Minimum necessary to achieve objectives**
  - Overall benefits to the community justify costs
  - Kept simple to avoid unnecessary restrictions
  - Targeted at the problem to achieve the objectives
  - Not imposing at unnecessary burden on those affected
  - Does not restrict competition, unless demonstrated net benefit
- **Not unduly prescriptive**
  - Performance and outcomes focus
  - General rather than overly specific
- **Accessible, transparent and accountable**
  - Readily available to the public
  - Easy to understand
  - Fairly and consistently enforced
  - Flexible enough to deal with special circumstances
  - Open to appeal and review
- **Integrated and consistent with other laws**
  - Addresses a problem not addressed by other regulations
  - Recognises existing regulations and international obligations
- **Communicated Effectively**
  - Written in ‘plain language’
  - Clear and concise
- **Mindful of the compliance burden**
  - Proportionate to the problem
  - Set at a level that avoids unnecessary costs
- **Enforceable**
  - Provides the minimum incentives needed for reasonable compliance
  - Able to be monitored and policed effectively

---

Figure 2: Summary of OECD Principles as set out in Argy and Johnson (see n 1003)

As identified in this thesis, the requirements of the regulatory process correlate with the principles of the ‘rule of law’,\(^{1004}\) upon which modern regulatory practices are essentially modelled.\(^{1005}\) Therefore, for the purposes of this thesis, I have used the rule of law concepts discussed in Salembier’s work as a proxy for the requirements of the regulatory process. I consider this appropriate given the literature on topic is considerably advanced, and though not universally accepted, has gained a special status in legal thinking internationally that is independent of the precise form of legal system in question.\(^{1006}\) Its utility in the context of the development of aviation law has also been noted by Huang as an appropriate basis for improving the quality of ICAO-level guidance.\(^{1007}\)

---

\(^{1004}\) Farrar, above n 835, 262; Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 166, 170.


\(^{1006}\) See, eg, Bartsch, above n 259, 11; Farrar, above n 835, 258, 259.

\(^{1007}\) Huang, above n 249, 226; See generally, Huang above n 249, ch 5.
For present purposes I wish to deal with this broad topic in terms of the following 5 principles of the rule of law as enunciated by Salembier,\textsuperscript{1008} which he concluded to be the most relevant to the design of a regulatory system:\textsuperscript{1009}

(a) the requirement to make rules;
(b) the requirement that rules be workable;
(c) the requirement to publicise rules or make them available;
(d) the requirement for some stability in rules; and
(e) the requirement that rules be impartially interpreted and applied.\textsuperscript{1010}

I will briefly elaborate on these principles in order to propose how they can be used as guidance for developing and evaluating classification schemes for UAS.\textsuperscript{1011}

1 \textit{The Requirement to Make Rules}

It may seem obvious that an effective rule is one that is actually made;\textsuperscript{1012} however, the point is that the rule so made should \textit{actually} direct or guide conduct. That is, it should be a rule that contains both subject and object. If there is too much leeway in terms of what is required or an excess of discretion afforded to the regulator in interpreting a rule, then technically rules are not created because there is no direction or guidance, no standard of conduct.\textsuperscript{1013} Rather, a case-by-case assessment is involved and which Salembier notes ‘contravenes… the rule of law’.\textsuperscript{1014} The scope of application of the rule, the requirements


\textsuperscript{1009} Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 171.

\textsuperscript{1010} These are broadly consistent with the 8 precepts espoused by Lon Fuller, set out in Farrar, above n 835, 28.

\textsuperscript{1011} Farrar, above n 835, 258 summarises Fuller as having noted the principles as being ‘generality, adequate promulgation, avoidance of retroactivity, clarity, avoidance of contradiction and consistency between rule and administrative action’: Farrar notes that others have referred to the relevant principles as ‘public participation, legitimacy, rationality and fairness’. Farrar concludes that the latter are possibly better regarded as exhibiting standards of good legal craftsmanship or process: at 258.

\textsuperscript{1012} Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 171.

\textsuperscript{1013} Ibid.

\textsuperscript{1014} Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 171.
of the rule, and the benefits and consequences that flow from compliance or non-compliance, must be apparent. I refer below to this requirement as one requiring ‘comprehensive’ rules.1015

2 The Requirement that Rules be Workable

The requirement for rules to be ‘workable’ imparts a practical consideration: do the rules work in practice? Do they make sense? This needs to be considered in terms of both the express, written rules, and the underlying rationale upon which the express rules are based, which would seem to be mandated by the requirement that rules be both ‘understandable and mutually consistent’.1016 On one level, the requirement may be thought to reflect largely in drafting considerations. There is a plethora of legal commentary on that topic, but it suffices to say at this point that rules should be drafted clearly and in a manner that is comprehensible and understandable to users. In general terms, this requires rules to be set out as simply and concisely as is possible. If rules are complex, even though decipherable, users may need to seek expert help in doing so, raising regulatory costs.1017

Looking beneath the surface, however, to be understandable there needs to be a connection between the rationale and the practical consequences. It is not enough that the written words alone are clear. To be understandable (and workable), the rationale underlying the rule must be accurately reflected in its effects, and taken together, the rationale and the rules must make sense. In that regard, rules should be consistent with the source of authority. Where that is not the case, disputes will inevitably arise as to the meaning of the words, requiring judicial intervention and raising the costs of participation in the system.1018 Salembier proposes that rules must therefore be feasible in so far as they are possible to comply with, as well as in an economic sense.

1015 In doing so, it is not my intention to create a fixed label. Such concepts are too broad to be covered by a singular word. Therefore this description is used only for ease of reference.

1016 Ibid 172.

1017 Ibid 173.

1018 Ibid 173.
3 The Requirement to Publicise Rules or Make them Available

Before regulations can be understood, they need to be accessible to users. This is generally acknowledged in modern legal systems and improving ‘access to justice’ has been a major focus of law reform over the past two decades. Efforts to improve accessibility can be seen in elements of the regulatory process in Australia, take for instance the publication of RIS,\textsuperscript{1019} and the need to lodge explanatory statements.\textsuperscript{1020} Salembier notes though that there is more to the requirement; namely, that users must be assured that the ‘economic playing field is level’\textsuperscript{1021} and therefore that the rules are the same for everyone.\textsuperscript{1022} He notes, more importantly, that where differences in treatment are apparent, these differences must publicised and justifiably explained.\textsuperscript{1023} Exemptions from compliance ought also to be made known and justified. That requirement for justification would seem, in the context of the ‘better regulation’ agenda, to require legal or evidentiary justification, for instance by reference to a cost/benefit or risk analysis.\textsuperscript{1024} There must be, at least, a justifiable reason for different treatment applied to one group or activity, as opposed to others. Generally speaking, this requirement echoes a desire for ‘transparency’.

4 The Requirement for Some Stability in the Rules

The rule of law requires stability from regulations, so that users have enough time to understand the rules, adapt to them and plan their business.\textsuperscript{1025} This normally requires rules to have prospective rather than retrospective application, and stability in so far as the rules are not constantly changing such that users are unable to adapt.\textsuperscript{1026} In that regard,

\begin{itemize}
\item \textsuperscript{1019}See, eg, OBPR’s requirements, summarised above.
\item \textsuperscript{1020}See, eg, \textit{Legislative Instruments Act 2003} (Cth), s 26.
\item \textsuperscript{1021}Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 172.
\item \textsuperscript{1022}See Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 4.
\item \textsuperscript{1023}Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 172.
\item \textsuperscript{1024}See the requirements of the OBPR, set out above. For instance, the \textit{Best Practice Regulation Handbook}, above n 945 notes that ‘[t]he size of a risk is generally characterised by the likelihood of an event occurring (ie – the probability of the adverse event or harm occurring) and the size of the impact should the event occur… Measuring risk can be a difficult task but can be achieved using reliable sources of information. Quantifying the magnitude of the risk is an important first step because it will inform the impact analysis (and cost-benefit analysis) at a later stage of the RIS process… Some risks, however, will be very difficult to quantify: in these cases, sound qualitative assessments can be used to supplement quantitative analysis.’ \textit{Best Practice Regulation Handbook}, above n 945, 78, 79.
\item \textsuperscript{1025}Salembier, ‘Designing Regulatory Systems - Part I’, above n 58, 172.
\item \textsuperscript{1026}Ibid.
\end{itemize}
stability fosters certainty, which the rules must strive to create. As Salembier discusses, there is safety in certainty and that generates both increased compliance and increased investment.  

5 The Requirement that Rules be Impartially Interpreted and Applied

Impartial interpretation and application also stems from a requirement for certainty – there should be no surprises and enforcement of the rules should be uniform, expected and equitable. This is an issue relating to the creation of excessive discretion on the part of the regulator, but it also speaks to the need for the consequences of breaking the rules to be known. There is therefore a need to ensure that clear rules are drafted, as well as a need for an assurance that the system will operate impartially in the event a decision is challenged. In that regard, the design of the rule must facilitate impartial, and consistent, enforcement of the rule if breached.

In summary, despite the many sources of regulatory processes from which guidance can be obtained, many common concepts are shared between them. Further still, many of these concepts echo those expressed in the current thinking in terms of UAS regulation; note the recurrence of terms such as ‘justifiable’, ‘logical’, ‘impartial’ etc.

It can be seen from the above that the regulatory process is comprised of a multitude of sources, encompassing a broad range of perspectives including legal, political, technical and economic. This reflects the multi-disciplinary nature of regulation; a legal approach alone and divorced from these other factors cannot provide a complete answer. It has been suggested that technical perspectives may encounter the same limitation. For these reasons, I argue that a legal perspective to the classification of UAS can assist in progressing the matter. Failing to identify the legal perspective may result in identifying

---

1028 Ibid 173.
1029 Ibid 176.
1030 Ibid 173, 177.
1031 Huang, above n 249, 7. Farrar, above n 835, 257 notes that boundaries between law and ‘not law’ are not clearly drawn: ‘[This] is a source of both strength and weakness. It avoids the danger of remoteness from everyday life and thinking. On the other hand, it results in uncertainties and gaps’.
1032 See Clothier et al, Definition of Airworthiness Categories, above n 3, 9, 10.
some aspects of the regulatory process (ie – the need for risk assessment and economic measures) but not others (for instance, the need for good legal process and good legal craftsmanship).

Thus the regulatory process necessarily requires consideration of legal political, technical and economic factors. In so doing, the regulatory process represents a system of ‘checks and balances’ that have developed in the law in its regulatory dealings with these other disciplines based on the lessons learned in lawmaking over time. In essence, regulatory process represents regulatory ‘best practice’, as Salembier explains:

In order to avoid [weaknesses] and to maximise the efficacy and predictability of regulatory rules, an effective regulatory process will incorporate a system of procedural rules and practices respecting the manner in which regulatory rules are developed and enacted… A regulatory process that incorporates the right meta-rules will ensure the effectiveness of the rules made under it.

These are mechanisms that are designed to improve the effectiveness and efficiency of regulation – the very question to which the collection of desiderata stated for UAS regulation are directed.

Taking the meta-rules together with the objectives provided by way of the primary legislation already existing in modern aviation systems, it is possible to visualise both the general principles and the means to obtaining them, and thus to construct the critical certification regime for UAS. A general framework of reference can therefore be established for the purposes of designing and evaluating proposals for UAS classification.

---

1033 See Farrar, above n 835, 257.
1034 See Huang, above n 249, 224.
1035 The fact is that whether or not certain approaches, for instance, the OBPR’s, are technically ‘legal’ in nature, they must be complied with in practice. In doing so, regulators must necessarily traverse the question of ‘effectiveness’ and hence the achievement of their legal mandates. That being the case, an approach based on an analysis of the relevant law remains persuasive, relevant and necessary. In that regard, Farrar, above n 835, 258 advocates ‘good legal craftsmanship’ and ‘good legal process’, which are said to be part of the ‘rule of law’.
1036 See for instance the Best Practice Regulation Handbook, above n 945.
1037 Salembier, ‘Designing Regulatory Systems - Part II’, above n 919, 1.
1038 By way of example in the aviation context: ‘…the feedback gained through consultation with industry was unanimous in support of aviation rules that were simple, unambiguous and focused on aviation safety… With that in mind, CASA supported a working motto of ‘safety through clarity’ throughout the reform process.’: Bartsch, above n 259, 147.
The means by which the framework can be generated is demonstrated below by reference to the classification contained in *CASR Part 101*.

**F Applying the Legal Guidance**

The utility of Salembier’s work in the present context is that it provides an accessible and relevant template for approaching the design and evaluation of a UAS classification scheme for UAS part of a broader system of rules. For instance, Salembier’s work can provide a means of resolving certain unknown variables by situating the task of classifying UAS within the broader context of the regulatory system as a whole. For instance, using Salembier’s work provides the following template:

(a) a regulatory system is comprised of a regulatory regime, being the substantive ‘rules of conduct’, and a regulatory process, being the meta-rules who govern the types of rules permitted to comprise the regulatory regime and the way in which they are established;

(b) the regulatory regime is in turn comprised of primary and secondary legislation;

(c) the primary legislation sets out the governing principles, or the objectives, of the regulatory regime whilst the secondary legislation effectively sets out the content;

(d) the regulatory process guides the development of the primary and secondary legislation;

(e) the test of quality of a regulatory system (being comprised of primary and secondary legislation and the meta-rules) is the question of whether or not the system, on the whole, is effective;

(f) an effective regulatory system is one that obtains its objectives; and

(g) a regulatory system can be assisted in obtaining its objectives (and thus be effective) by adhering to the principles of the rule of law.

At that point, one has a basic equation for the design of an entire regulatory system. The critical elements (or variables) are underlined above; the only unknown element is that of...
the content of the regulatory regime, the secondary legislation (see (iii) above). Essentially, the end goal (derived by the objectives of the primary legislation) is known and a process to follow in order to get there is available (via the regulatory process aspects).

If the concept of classification is viewed as being an essential first step to creating those rules (and in fact part of those rules), and it is also accepted that the quality of a classification scheme ought to be evaluated in the same manner as the quality of regulations generally (as this thesis argues), then it is possible to apply the regulatory system concept in order to construct a framework for the design and evaluation of a UAS classification scheme. That is, the crucial framework of reference can be constructed upon legal principles.

To elaborate, a framework can be constructed for UAS classification based on the regulatory system concept, comprised of the:

(a) objectives of the primary legislation, derived from analysis of the regulatory regime (in the example above, the *Aviation Act*); and

(b) rule of law principles (derived from the regulatory process) that will ensure as far as possible that the secondary legislation complies and achieves the objectives of the primary legislation.

This process can be mapped visually by showing the decisions to be made in relation to classification, the influence of the rule of law principles on those decisions, and the end towards which the decisions are directed. The idea that a certification regime can be viewed as comprising decisions as to the relevant criteria, class boundaries, class designations and corresponding rules – namely, the key decisions discussed above – has

---

1040 Palmer and Clothier, above n 36, 7; DeGarmo, above n 42, 240, 3-1, 3-2; Maneschijn et al, above n 42, 353; Maddalon et al, *Perspectives on Unmanned Aircraft*, above n 8, 5; AIAA, above n 42, iv.
been outlined in Chapter V above. Under this approach, the problem can be mapped accordingly:

![Diagram of Rule of Law, Classification Decisions, and Regulations]

*Table 29: Breakout Showing Application of Rule of Law Principles to Key Decisions*

To elaborate on the diagram, and by way of summary to this Chapter, the rule of law principles are designed to increase the effectiveness of the regulatory system by ensuring that the system attains its objectives. These objectives were analysed earlier in this Chapter and are summarised on the right side of the chart, signifying the ultimate goals. On the left, the rule of law principles are summarised. The 4 key decisions of classification sit as the interface between the two. That is, 4 key decisions must be made and the decisions reduced to writing as law; these decisions incorporate within them (in the making of such decisions) the core aspects of purpose, method and structure. In making the decisions and producing secondary legislation, the regulator must seek to achieve the relevant objectives of the regulatory system. Using the rule of law principles to guide the making of these decisions means it more likely that the regulator will succeed. These concepts therefore represent the basic construction of a framework of reference that is needed for the purposes of understanding and improving UAS classification schemes, and assisting in the resolution of debates as to the appropriate content of a certification regime. The next Chapter demonstrates how this guidance discussed in this Chapter can be utilised as a framework of reference for analysing the classification in the existing *CASF Part 101* regulations.
This Chapter combines the numerous concepts examined in this thesis to this point in order to test the functionality of the basic framework of reference discussed in Chapter VII against the real-world example classification found in *CASR Part 101*. Specifically, the guidance obtained through an examination of the regulatory system (in which the UAS certification regime is to be found) is mapped to the key decisions. These key decisions are closely related to the other core aspects of purpose, method and structure – these aspects create the background logic processes that underpin the decision-making. For the purposes of this analysis, each of the core aspects are set out in order to fully explore the construction of the *CASR Part 101* classification scheme. These are then assessed against the regulatory system concepts – that is, the *CASR Part 101* scheme is vetted against the rule of law principles on the basis that these principles ensure (as far as possible) the creation of effective rules that achieve their legal objectives. These considerations form the basis for conducting a legal analysis.

In the course of the following analysis, it is useful in some instances to contrast CASA’s position with those employed elsewhere in order to illustrate gaps or propose alternatives not considered in *CASR Part 101*. This contrasting is particularly useful in areas where there is a need to rely on technical knowledge that cannot be supplied by a legal perspective (such as consideration of the physical, performance, and risk characteristics of UAS). This does not detract from the application of the legal perspective; rather, it reinforces the utility of a legal perspective in framing debate and providing general guidance where technical consensus is lacking.
A  CASR Part 101 Classification Scheme

The UAS classification scheme contained within CASR Part 101 is not expressly set out in the statutory instrument.\textsuperscript{1041} A user must look to the following definitions contained in regulation 101.240 to ‘compile’ the classification:

‘UAV’ means unmanned aircraft, other than a balloon or kite;

‘Micro UAV’ means a UAV with a gross weight of 100 grams or more;

‘Small UAV’ means a UAV that is not a large UAV nor a micro UAV;

‘Large UAV’ means any of the following:

(a) An unmanned airship with envelope capacity greater than 100 cubic metres;
(b) An unmanned powered parachute with a launch mass greater than 150 kilograms;
(c) An unmanned rotorcraft with a launch mass greater than 100kg; or
(d) An unmanned powered lift device with a launch mass greater than 100 kilograms.\textsuperscript{1042}

Interestingly, there is actually no definition in CASR Part 101 of the term ‘unmanned aircraft’. Additionally, the relevant rules attaching to each class are not set out in a manner that directly corresponds to each of the class definitions. Rather, CASR Part 101 contains regulations arranged by topic (in a sense) and arrayed throughout the text of Part 101. This text contains various references back to the relevant definitions.

B  Purpose

CASR Part 101 does not contain any overt statement of purpose, thus the purposes of the classification scheme within it must be ascertained by way of a process of statutory interpretation, as set out above. A user of the classification scheme must have regard first to the objects of the Aviation Act, which, as set out above, only deals in terms of general concepts, evincing the primacy of safety but also placing importance on economic concepts such as fostering growth.\textsuperscript{1043} It can also be surmised that the purpose of classifying UAS aligns with the performance of CASA’s functions as set out in s8 of the

\textsuperscript{1041} Note that CASR Part 101 refers to ‘UAVs’: See CASR Part 101 reg 101.240.
\textsuperscript{1042} See CASR Part 101 reg 101.240.
\textsuperscript{1043} See above n 330.
Aviation Act relating to the developing of safety standards, the task of licencing aircraft and the analysis of risk factors and safety trends (inter alia).

For present purposes, regard may also be had to other, extrinsic documents such as Advisory Circulars, RIS and NPRMs, as well as other discussion documents produced by CASA by way of background. All of these documents may provide some indication of the purpose of the classification scheme, though, legally speaking, primacy must be afforded to the terms of the Aviation Act (and delegated legislation). For instance, in seeking to give effect to its statutory mandate, in June 1998 (at the time CASA proposed to first implement CASR Part 101) CASA stated that the purpose of Part 101 was to ‘establish both general and specific standards for all types of unmanned aircraft and rockets’ as well as stating a number of other, more specific objectives for the regulation, being to:

(a) revise the existing regulations covering the operation of unmanned aircraft and rockets;
(b) consolidate existing legislation covering the operation of unmanned aircraft and rockets, contained in prior directives issued by CASA and the Civil Aviation Regulations 1988 (Cth), into one regulation;
(c) simplify compliance with the regulations;
(d) where possible, delegate responsibility for administering particular aviation activities to industry;
(e) as far as possible, harmonise Australian legislation with that of major overseas nations; and
(f) reduce the reliance of the legislation on exemption(s).

Similar statements were made in the CASA RIS published in 2001. While the twin goals of safety and growth are apparent in these specified objectives set out above, it is also clear that at this point in time that CASA perceived its objectives in regulating UAS

\[\text{Note also that, strictly speaking, reference to such material may not be permitted by a court; see Chapter VII.D.}\]

\[\text{CASA NPRM 1998, above n 452, 1; see also the Explanatory Statement, Civil Aviation Amendment Regulations 2001 (No. 4) 2001 No. 34 (Cth).}\]

\[\text{CASA NPRM 1998, above n 452, 5.}\]

\[\text{CASA RIS, above n 438.}\]
as relating more to administrative issues than to the core issue of ensuring safety. Aside from noting peripherally the importance of establishing ‘types’, neither the CASA NPRM 1998 nor the subsequent CASA RIS consider the topic of classification in any detail.

CASA’s further proposal in CASA NPRM 2014 (relating to its review of CASR Part 101 and proposed issue of new rules) is a more comprehensive document. Though it does not define the purpose of the regulatory action precisely, it is clear that safety standards are of primary importance, and specifically emphasised:

(a) the importance of understanding the actual risks of different types of UAS;
(b) the need for the use of terminology that aligns with the current thinking in UAS regulation and international developments; and
(c) that ‘categorisation’ of UAS is a critical element in connecting the investigation of risks to the creation of safety standards.

Again, these statements fall short of expressing the precise purpose of classification, but recognise more clearly the role that classification can play in assisting in the achievement of the statutory purpose through categorisation or classification (in this case, based on the risks of UAS operations). By way of contrast, the observations in NASA’s studies are more useful, noting that the purpose of UAS classification is to facilitate a standards-based approach to airworthiness certification of UAS, by providing a descriptive framework for grouping together UAS with similar risk characteristics that would then be held to similar airworthiness standards. Further, NASA’s studies also highlight that classification has a role to play in facilitating consideration of the economic aspects of UAS operations.

Without further clarification of the relevant purposes by CASA, there is significant doubt

---

1048 CASA NPRM 1998, above n 452, 1.
1049 CASA NPRM 2014, above n 503, 2, 9.
1050 CASA NPRM 2014, above n 503, 2, 8.
1051 CASA NPRM 2014, above n 503, 8.
1052 Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 6.
1053 Maddalon et al, Perspectives on Unmanned Aircraft, above n 8 states that a standards-based approach through classification facilitates planning from a manufacturer’s perspective in terms of design and cost, as well as ensuring a consistent and level playing field: at 4.
as to the effectiveness of the *CASR Part 101* scheme on the whole, bearing in mind the importance of purpose from a legal perspective.\(^{1054}\)

### C Method

There is little discussion about how precisely the Part 101 classification was developed, and the limited available information is contradictory. For instance, CASA documents state that:

(a) the ‘classifications were *developed empirically* without reference to other aeronautical standards and may well require review in light of experience’;\(^{1055}\) and

(b) the classification scheme *was* derived based on ‘a risk management approach’;\(^{1056}\)

This suggests that some kind of theoretical basis was utilised in developing the scheme. The documents containing these statements are not generally available, but they were written contemporaneously with the publication of *CASR Part 101* by a person involved in its preparation.\(^{1057}\) However, the *CASA NPRM 2014* says categorically in relation to the *CASR Part 101* classification that ‘*[t]hese weight limits were based on the weights pertaining to model aircraft and are not risk-based*.\(^{1058}\) Whatever the true case, the confusion alone undermines the effectiveness of *CASR Part 101*. As such, it must be concluded that the methods employed were more or less subjective or arbitrary, particularly in light of the comment that:

> CASA currently imposes operational restrictions on small RPA weighing more than 100g because it does not have sufficient data on the potential injury that could be caused to people on the ground resulting from blunt ballistic impact.\(^{1059}\)

\(^{1054}\) See the work of Brennan and Starr summarised above in Chapter V.B and VI.C.

\(^{1055}\) Walker, *Evolution*, above n 33, 8 (emphasis added). Refer to above n 33 for further information regarding this source.


\(^{1057}\) See the references to Mr Walker in *CASA NPRM 1998*, above n 452, 8.

\(^{1058}\) *CASA NPRM 2014*, above n 503, 8 (emphasis added).

\(^{1059}\) Coyne, above n 143, 6.
This supports the view that the classification scheme was not formulated on the basis of any formal risk study based on (for instance) statistical or mathematical data. The *CASA NPRM 2014* states a desire to move away from such arbitrary methods, espousing the need for a more rigorous, risk-based categorisation based on kinetic energy measurement.\(^{1060}\) Despite stating that CASA ‘has investigated’ this matter, it does not set out clearly how this has occurred, nor the results of that investigation.\(^{1061}\) Thus the existing and proposed methods remain unclear. As the present classification scheme stands, its methods are opaque, significantly reducing the effectiveness of the scheme. In that regard, the CASA scheme could benefit from the fulsome methodological explanations of the kind found in the work of Clothier et al,\(^ {1062}\) Dalamagkidis, Valavanis and Piegl,\(^ {1063}\) and Fraser and Donnithorne-Tait.\(^ {1064}\)

### D Structure

The structures involved the Part 101 classification are not easily visible in the written format in which they are presented. As set out above, the creation of the classification scheme involves the definition of certain terms within *CASR Part 101*, which definitions are then referred to elsewhere in the regulations. Nonetheless, the words themselves are laws.

A review of related literature finds the scheme presented in this way (albeit in a document that is not generally available and not of any legal force in its own right).\(^ {1065}\)

<table>
<thead>
<tr>
<th>UAS Class</th>
<th>Micro UAV</th>
<th>Small UAV</th>
<th>Large UAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airship</td>
<td>N/A</td>
<td>&lt; 170m³ (envelope)</td>
<td>&gt; 170m³ (envelope)</td>
</tr>
<tr>
<td>Powered Parachute</td>
<td>N/A</td>
<td>&lt; 150 kg</td>
<td>≥ 150 kg</td>
</tr>
<tr>
<td>Aeroplane</td>
<td>&lt; 100g</td>
<td>≥ 100g &lt; 150kg</td>
<td>≥ 150kg</td>
</tr>
<tr>
<td>Rotorcraft</td>
<td>&lt; 100g</td>
<td>≥ 100g &lt; 100kg</td>
<td>≥ 100kg</td>
</tr>
</tbody>
</table>

\(^{1060}\) *CASA NPRM 2014*, above n 503, 8.
\(^{1061}\) See *CASA NPRM 2014*, above n 503, 8.
\(^{1063}\) See, eg, Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50.
\(^{1064}\) Fraser and Donnithorne-Tait, above n 211.
\(^{1065}\) Walker, *Airworthiness Standards*, n 503, 1. Refer to above, n 503 for further information in relation to this source. See also the table in Maddalon et al, *Perspectives on Unmanned Aircraft*, above n 8, 27.
In this light, it is clear that all classes are subclasses of ‘unmanned aircraft’, as defined. However, there are additional, invisible and important structures at play. First, it appears the scheme is constructed of 5 ‘types’ each with 3 ‘sub-types’ or classes, in terms of its vertical structure: UAS-AC → Aeroplane Type → Small UAS-AC (for instance, and noting that the term ‘UAV’ is used in *CASR Part 101*). This is a relatively simple hierarchy, particularly because the ‘types’ are relatively distinct, though query the continued evolution of UAS towards new configurations, such as ‘tilt-rotor’ and ‘tilt-body’, which defy allocation to the above typology.

In terms of the horizontal structure, the scheme generally represents a monothetic classification within each of the ‘types’; that is, a scheme whereby all of the members of each class exhibit the same characteristics, albeit to different degrees. In this case, the primary characteristic (aside from being unmanned) is the mass of the UAS-AC. The scheme utilises fixed, numerical ‘cut-offs’ in specifying class boundaries consistent with Brennan’s observations relating to monothetic classification structures. This affords a degree of simplicity to the scheme. However, in light of the lack of explanation by CASA as to the methods and structures utilised in producing the classification scheme, the scheme may also be described as ‘artificial’ in the sense that the ordering has been imposed on UAS at the outset, rather than learned by reference to available data. In that sense, the scheme might also be described as ‘subjective’ given its lack of statistical study.

This raises practical questions as to whether the scheme establishes ‘real similarities and differences’; for instance, in assessing the internal homogeneity of the scheme, it is very questionable as to whether a UAS-AC with a mass of 149g and 149kg (both Small UAVs) are ‘similar’ in any relevant sense. Having regard to purpose, it is difficult to see why such UAS ought to be subjected to the same airworthiness or operational requirements. Similar

---

1066 See *CASR Part 101.240.*
1067 See the discussion of UAS terminology and typology in Chapter II.2 above.
1068 Brennan, above n 470, 222.
questions arise with respect to a UAS-AC of 151kg and 15100kg (both being Large UAS). Of course, the lack of clear purpose in generating the CASA scheme (as opposed to NASA’s conclusions as to purpose, for instance) may contribute to the apparent lack of homogeneity. A further study of the horizontal structures of the CASR Part 101 scheme is set out below by reference to the key decisions.

E The Key Decisions

Classification schemes inherent within written laws often are not presented in tabular or graphical form. Some classifications may therefore not be readily recognisable as such. However, conceptualising a classification as a series of key decisions may assist in analysing a classification scheme in order to expose the methods, purposes and structures that comprise the key decisions. This is an important step towards understanding UAS classification from a legal perspective, as a written law, and in developing a framework of reference.

As a starting point, the CASR Part 101 scheme can be presented graphically, as it is above. Taking just the class of fixed wing UAS above, the criteria, boundaries, and names that comprise the classification scheme can be identified and overlaid on the diagram as follows (using the tabular form presented above):1070

1069 Fraser and Donnithorne-Tait, above n 211, 158 raise the question as to why (for the purposes of the 150kg EASA weight boundary) a 160kg UAS-AC and a 140kg UAS-AC ought to be treated differently for airworthiness purposes.
1070 See Walker, Airworthiness Standards, n 503, 1. The underlying table contained in Figure 3 below is as presented by Walker, Airworthiness Standards, n 503, 1 but amended (by overlay) to illustrate the ‘key decisions’ as explained in this thesis. Refer to above, n 503 for further information in relation to this source.
As set out above, these key decisions can be assessed against the rule of law principles, which are designed to ensure, as far as possible, that a lawmaking exercise creates effective laws and achieves its goals. In the following section I have analysed each of the 4 key decisions against the rule of law principles.\textsuperscript{1071}

1 \textit{Criteria}

\textit{Comprehensiveness:} The primary attribute of relevance for classification is the maximum take-off mass of the UAS-AC. The use of a single criterion (mass) favours fixed cut-offs and provides relative certainty in relation to the allocation of individual UAS to a class.

The mass (or MTOW) of a UAS-AC is unlikely to significantly change over time as this is a core design element of the UAS-AC, and the criterion covers the full possible spectrum of UAS-AC from 0 to infinity. However, the precise meaning of the term ‘launch mass’ presently used in \textit{CASR Part 101} is unclear; this is not a defined term in the regulations and is not a term ordinarily used with respect to conventional aviation.\textsuperscript{1072}

\textsuperscript{1071} Although the rule of law principles are not applied directly to the purposes, methods and structures, these issues are captured within consideration of the key decision (that is, the key decision \textit{exhibit} the purposes, methods and structures used in the classification) and therefore still form part of the consideration.

\textsuperscript{1072} In \textit{CASA NPRM 2014}, above n 503, 2 CASA refers to the ‘gross weight’ of the UAS-AC.
Workability: The use of a mass criterion affords the scheme an element of simplicity given the use of similar criterion in existing regulations for conventional aircraft.\textsuperscript{1073} and globally in relation to UAS regulation.\textsuperscript{1074} User-friendliness is also promoted by the use of one characteristic (from amongst the full range of the UAS’ characteristics) to determine class membership.\textsuperscript{1075} As to whether the use of the criterion promotes feasible rules, this is difficult to judge given the lack of explanation by CASA as to the purposes, methods and structures. Based on NASA’s conclusions as to the role of classification in facilitating risk and cost assessment,\textsuperscript{1076} CASA has not comprehensively studied or explained the connection of the mass criterion with these concepts.\textsuperscript{1077} It is relatively clear that the question as to the basis for selecting criteria was not given close consideration at the time \textit{CASR Part 101} was prepared.\textsuperscript{1078}

Transparency: Although the simplicity and familiarity of the mass criterion facilitate the accessibility of the scheme, publication requires assurances that the economic playing field is equal and any differences in treatment are explained and justifiable. As set out in Chapter V.C.2, there is no consensus as to whether the mass criterion is appropriate for UAS, given the differences between UAS and conventional aircraft and the specifics of the risks associated with UAS. For instance, it has been observed that mass was traditionally used as a proxy for the number of passengers aboard an aircraft and a rough approximation of risk.\textsuperscript{1079} UAS have no passengers, and some have noted that mass does

\begin{itemize}
\item \textsuperscript{1073} See the reference to simplicity, minimisation of complexity and similar concepts in Clothier et al’s and Fraser and Donnithorne-Tait’s work: See Palmer and Clothier, above n 36, 14; Fraser and Donnithorne-Tait, above n 211, 170.
\item \textsuperscript{1074} Particularly noting that one of the regulatory objectives of \textit{CASR Part 101} was to achieve harmonisation: \textit{CASA NPRM 1998}, above n 452, 5.
\item \textsuperscript{1075} Brennan, above n 470, 215.
\item \textsuperscript{1076} Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 4, 6.
\item \textsuperscript{1077} Some have tried to study the costs in relation to weight: See, eg, Casarosa et al, above n 392.
\item \textsuperscript{1078} See the limited information as to the costs and benefits involved and the limited information as to how the projected costs were calculated (as well as the truncated consideration of these matters with respect to the mass of the UAS-AC): \textit{CASA RIS Unmanned Aircraft and Rockets}, 6. It appears no formal, detailed risk assessment was conducted in the course of preparing the \textit{CASA RIS}. Cf \textit{FAA NPRM}, above n 147. The latter approach of the FAA includes a more comprehensive analysis of the likely costs.
\item \textsuperscript{1079} Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 14; See also Clothier, 1005; Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111, 323; Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50, 514.
\end{itemize}
not accurately predict the actual risks involved with UAS operations.\textsuperscript{1080} Others have noted that mass does not readily correlate with other characteristics of UAS design or performance.\textsuperscript{1081} Having regard to the objects of the \textit{Aviation Act} and its primary focus on safety, it is questionable whether the mass criterion permits justifiable distinctions to be made. Again, a full assessment is hampered by the lack of available explanation of the purposes, methods and structures used by CASA, and the fact that the scheme has not been subjected to rigorous regulatory impact assessment, including cost/benefit and risk analysis; the questionable links between mass and risk for UAS observed in the current approaches may indeed prevent that from occurring. It can be said that the limited amount of information itself means that the scheme complies only in a limited way with this principle.

\textit{Stability}: The use of a mass criterion itself means the classes ought to be relatively stable in so far as all UAS-AC can be positively allocated to some part of the mass spectrum. However, as has been set out above, new mass classes are likely to ‘emerge’ over time, as has been the case with the growth in the supply and demand for smaller UAS in the last 5 years. For instance, the UVS International classification (discussed above) features 15 classes of UAS, compared to the 3 incorporated within \textit{CASR Part 101}.\textsuperscript{1082} In that regard, it is likely that weight classes will need to change over time, as the technology develops, as has been observed in CASA’s recent decisions to reconsider the existing weight categorisation to include a further mass bracket.\textsuperscript{1083} It is unclear at this juncture with alternative methods such as risk-based classification have greater prospects for producing a stable scheme, though the ‘modular’ approach of Clothier et al involving numerous type

\begin{footnotesize}
\begin{enumerate}
\item[1081] See, eg, Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3, 7; Palmer and Clothier, above n 36, 14
\item[1082] Looking only within the ‘aeroplane’ type of UAS, there are only 3 possible weight classes: ‘micro’, ‘small’ and ‘large’.
\item[1083] CASA, NPRM 2014, 8. See also the FAA’s consideration as to whether to include a ‘micro’ class in its developing rules: \textit{FAA NPRM}, above n 147, 9557.
\end{enumerate}
\end{footnotesize}
categories, and numerous operational categories may offer additional flexibility that can cater for a broader array of ‘types’.\textsuperscript{1084}

\textit{Impartiality:} Finally, the mass criterion means that the scheme can be implemented and used with relative impartiality – the mass of a UAS-AC is easily ascertainable and readily apparent (within reason) by way of visual inspection to regulators and users; there is little potential for ‘grey areas’. However, there remains the potential for an uneven application of the rules if, as is it said by some, mass does not fully or accurately describe the risks of UAS, leaving open questions as to whether rules may be improperly framed or enforced as a result. That is, if mass is not an appropriate measurement of risk, and if ‘risk’ is taken to be the most appropriate classification criteria, then there remains the underlying possibility that regulatory treatment will not be applied equitably or impartially.

2 \textit{Class Boundaries}

As with the choice of criteria, CASA has not explained the choice of class boundaries with specificity, which complicates analysis.

\textit{Comprehensiveness:} The class boundaries established under \textit{CASK Part 101} are comprehensive in the sense that the full mass spectrum for any possible UAS-AC is covered, and there are no gaps between classes. There is little room for discretion, though the description of ‘Small UAV’ may create ambiguity in that it does not actually describe the relevant weight bracket; rather it describes UAS-AC that are ‘not a Large UAV nor a micro UAV’,\textsuperscript{1085} leaving the user to make the inference.

\textit{Workability:} In a literal sense the class boundaries chosen can be read and understood relatively easily. Further, the low number of classes created (3) means that the scheme is workable in a practical sense (and is not overloaded by excessive distinctions). These aspects could be improved further by presenting the information in tabular form within the


\textsuperscript{1085} \textit{CASR Part 101} reg 101.240.
actual regulation. As to whether the boundaries proposed are feasible is more difficult to assess given the limited economic data and study utilised by CASA in the proposal. This issue is examined further by reference to the third principle (transparency) below.

Transparency: Aside from the noted lack of comprehensive explanatory material, CASA’s chosen boundaries are in fact quite difficult to understand (from an analytical perspective) for several reasons when considered against the requirement for differences in treatment to be explained and justified:

(a) Generally speaking, as the boundaries were selected apparently without reference (or limited reference) to a risk study, it is not apparent as to why the boundaries are significant from a safety perspective having regard to the objects of the Aviation Act. Save to say that the 150kg boundary may have been selected to achieve the harmonisation objective of the regime, it is not apparent whether the boundaries have any connection to any of the other relevant objectives;

(b) In that regard, it is also notable that 100g boundary does not align with any other regulations or proposals surveyed in Chapter IV. The decision is curious in that it the mass involved is extremely low, yet the next mass boundary of 150kg is relatively high (comparatively speaking) for a UAS-AC. The mass range between the two represents an extreme variety of UAS that do not at first glance appear to be ‘similar’, particularly bearing in mind that CASA does not refer to a 25kg boundary as is the case in numerous other regulatory approaches. It is also unclear as to why UAS-AC weighing less than 100g ought to be exempt from CASA’s scrutiny;

(c) The 150kg boundary is likely to have been simply adopted from EASA regulation (though that has not been clearly acknowledged by CASA). However, a study of the validity of the EASA boundary suggests that it has little relevance, and the EASA

1086 Walker, Evolution, above n 33, 8 (refer to above n, 33 for further information in relation to this source); Cf Walker, Airworthiness Standards, n 503, 1 (refer to above, n 503 for further information in relation to this source); See Clothier and Walker, Casualty Risk Analysis, above n 40, 2 in relation to the approach taken by CASA.
1087 See, eg, FAA (24kg), CAA (20kg), TC (25kg, 35kg), ASTM (25kg) (see Chapter IV.D for a review of each approach).
1088 Fraser and Donnithorne-Tait, above n 211, 158, query the differences, from a certification perspective, of a UAS-AC weighing 140kg and 160kg (compared to the 150kg demarcation).
CLASSIFYING UNMANNED AIRCRAFT SYSTEMS

A-NPA does not adequately explain why the 150kg limit was adopted as the delimiter between national and EU jurisdiction;\(^{1089}\) and

(d) Everything above the 150kg limit is considered by CASR Part 101 to be a Large UAV and therefore, the same in a regulatory sense, notwithstanding the extreme diversity of UAS that would fall within that class.

The relationship between the relevant boundaries and the actual application of rules in practice is unclear where CASA presently uses a case-by-case assessment process; this undermines the transparency of the scheme.

*Stability:* As set out above, although the boundaries appear prima facie to be relatively stable, it seems inevitable that more classes of UAS are needed in order to achieve appropriate ‘resolution’\(^{1090}\) for the classification scheme; that is, in order to create classes of UAS that are actually similar. In that regard it is notable that the CASA NPRM 2014 proposes the introduction of a further weight boundary at 2kg, making way for a ‘Medium’ class of UAS to be inserted for gross weight UAS-AC between 2kg and 150kg.\(^{1091}\)

*Impartiality:* Again, without better ‘resolution’ in the classification, and actual study of the risks and costs, there is the possibility of hidden biases occurring such as under or over regulating UAS due to the use of boundaries that do not properly coincide with sound, safety-based reasoning (and therefore, do not coincide with the objects of the Aviation Act). Similarly, this leads to difficulties in enforceability – if everything above 100g requires a certificate of airworthiness to operate above a populous area, how can this be policed, and how is this commensurate with the costs of certification and the risks? As noted above, in the absence of formal certification standards that permit certification, the case-by-case process that has resulted casts doubt on the degree of impartiality of the application of the rules. These questions are not answered by the current scheme.

---

\(^{1089}\) *JAA/Eurocontrol Report*, above n 59, Annex 1 states that the JAA determined the mass limit by review of the worldwide UAV fleet which showed that 23 of the 29 existing civil/commercial UAS-AC existing at that time had a mass less than 150kg: at 6. The boundary may have been adopted from a weight bracket utilised by the North Atlantic Treaty Organization: *TC*, above n 160, 2.


\(^{1091}\) *CASA NPRM 2014*, above n 503, 8. See also the FAA’s consideration as to whether to include a ‘micro’ class in its developing rules: *FAA NPRM*, above n 9557.
3 Class Designations

CASA utilises a simple class naming system that describe the size of the UAS-AC: Micro UAV, Small UAV and Large UAV.

Comprehensiveness: As the naming system essentially functions as a statutory definition, it is important to ensure that the names properly describe the relevant UAS. While the names appear acceptable prima facie, the significant inconsistency in the use of similar terms internationally may create latent ambiguity. Another issue needs to be addressed: the use of the term UAV does not align with the current use of the terms UAS or RPAS. In that regard, CASR Part 101 requires update to harmonise with ICAO guidance.  

Workability: As noted, the naming scheme is simple, and for that reason, relatively workable. However, CASA’s naming system does not align with those used in other jurisdictions. For instance, CASA use ‘Small’ to describe UAS between 100g and 150kg. However, the term is used in other proposals to describe variously UAS-AC that weigh between 2 to 25kg, less than 28kg, and between 10 and 500kg. It is notable that there is also an aspect of inconsistency inherent in the scheme in that it uses words relating to the size of the UAS-AC in order to describe characteristics that relate to mass. While there may be some correlation between size and mass (though this is not certain for UAS), the use of words such as ‘light’ or ‘heavy’ instead of ‘small’ and ‘large’ would appear preferable. These ambiguities appear to affect all aspects of the scheme; for instance, the scope and application of the scheme are unclear because the ‘shorthand’ descriptors for the classes are unclear.

Accessibility: As there is no explanation as to why the particular terms were chosen by CASA, it is difficult to assess compliance with this principle. One observation is that given the technical views as to the relationship between UAS mass or size and the relevant risks (to the effect that mass may not be an adequate measure of risk in its own right), it is

---

1092 This issue has been identified in the latest NPRM: CASA, NPRM 2014, 2.
1093 FAA NPRM, above n 147; sUAS ARC Report, above n 521, 22.
1095 Fraser and Donnithorne-Tait, above n 211, 171, 173.
questionable whether the terms referring to mass or size align with the safety objectives of the *Aviation Act*.

*Stability:* In light of the many terms used to describe UAS, it is unlikely that the names used can be viewed as stable, and that the names involved will likely change once ICAO (and also the FAA) have concluded their studies and formulating final regulatory initiatives. The lack of stability in the present names can be demonstrated by reference to the proposal in the *CASA NPRM 2014* which indicates that the label ‘Small’ will be reallocated to refer to UAS-AC with a gross weight between 100g and 2kg, with a ‘Medium’ label to be take over the 2 to 150kg spectrum.\(^{1096}\)

*Impartiality:* The issues concerning the inconsistent and ambiguous use of the names incorporated in *CASR Part 101* also affect the degree of transparency and impartiality in the scheme. For the reason that classificatory nomenclature acts as a proxy for the characteristics of the relevant class and is critical to information retrieval and storage,\(^{1097}\) the names become imbued with certain meanings within the industry, which shares its ‘dictionary of terms’.\(^{1098}\) The names used by CASA may therefore cause retrieval of inaccurate information because, for instance, the word ‘Small’ is used to describe very different UAS in other jurisdictions.

4 *Applicable Rules*

It is beyond the scope of this thesis to conduct a complete analysis of the effectiveness of the Part 101 rules; that is an exercise that requires the resources of a governmental department. A further issue is that there is a lack of available information as to precisely how CASA administers the *CASR Part 101* system as this occurs on a case-by-case basis.\(^{1099}\) However, the task of assessing the rules applicable to UAS is simplified by having first identified the foregoing 3 key decisions. By that means, when analysing the rules, one can reflect back upon the issues encountered at the preliminary level in terms of selecting criteria, boundary and names. This is consistent with my observation above that

\(^{1097}\) Brennan, above n 470, 207, 208.
\(^{1098}\) Ibid 207.
\(^{1099}\) *AAIF Report*, above n 11, 6
classes in a scheme cannot be properly analysed without reference to the relevant consequences, and vice versa, and further consistent with the analysis of the interconnection between the *protasis* and the *apodosis* of a given set of rules.\textsuperscript{1100} It is convenient to conclude the study with a preliminary analysis of the *CASR Part 101* rules against the rule of law principles. The relevant rules attaching to each class are summarised in Chapter IV.D.1.

*Comprehensiveness:* In terms of preliminary analysis of the rules under *CASR Part 101*, it can be said that the rules are not comprehensive in their scope and application. In fact, CASA has accepted that *CASR Part 101* does not provide guidance to the industry as to what is required by the rules.\textsuperscript{1101} For instance, although Small UAVs may apply for a certificate of airworthiness in order to operate over ‘populous areas’,\textsuperscript{1102} there are no published design standards.\textsuperscript{1103} Thus the rules are deficient and operations of Small UAVs over populous areas are effectively precluded.\textsuperscript{1104} Furthermore, the definition of ‘populous area’ itself is insufficient. For instance, *CASR Part 101* reg 101.025 states that:

> For this Part, an area is a *populous area* in relation to the operation of an unmanned aircraft or rocket if the area 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 or rocket) 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. (emphasis in original)

Clothier et al, for instance, have noted the ambiguities in the above passage.\textsuperscript{1105} The use of such a rule therefore affords too much discretion to the regulator. As such there is limited compliance with the first principle.

*Workability:* Although *CASR Part 101* is set out in a relatively concise manner, the above issues are encountered at a practical level. For instance, although it is relatively clear that

\textsuperscript{1100} See Chapter VII.F.
\textsuperscript{1101} Coyne, above n 143, 3.
\textsuperscript{1102} By *CASR Part 101* reg 101.280 only a ‘certificated UAV’ may operate over a populous area, essentially, and any such operation also requires CASA’s approval.
\textsuperscript{1103} Coyne, above n 143, 4.
\textsuperscript{1104} Coyne, above n 143, 3, 4; See also CASA, AC 101-1(0), above n 153, 9 [6.5.2].
Large UAVs must be certificated, and that only ‘certificated UAVs’\textsuperscript{1106} can operate over ‘populous areas’, the lack of design standards for airworthiness certification means that operators must engage in a negotiation process with CASA in order to reach an agreed specification.\textsuperscript{1107} This process is impractical for routine UAS operations,\textsuperscript{1108} and casts significant doubt as to whether the scheme is ultimately feasible; that is, it may not actually be possible to comply with, nor (even if it is possible), economically viable to do so. The case-by-case process that has emerged is ultimately only a temporary solution.

\textit{Transparency:} Taking the example about as to the lack of design standards, the private negotiation process results in a lack of publication to the broader group of participants,\textsuperscript{1109} and therefore provides no assurance that the playing field is equal. More than that, differences in treatment for the different mass classes are insufficiently explained and justified. For instance, it is difficult to understand the basis upon which a 150g Small UAV ought to be subjected to airworthiness certification similar to that imposed on a Large UAV (say one weighing 1,500kg). In that regard, as has been noted, there is an inadequate correlation between the ‘type’ and the ‘treatment’ due to the lack of correlation between the risk involved with the relevant UAS-AC and the objectives of the Civil Aviation Act.

\textit{Stability:} Although Part 101 has been in place and largely unchanged for a decade, CASA’s acknowledgements that the rules provide limited guidance and its statements that the rules have been under review for numerous years, mean that the rules are unstable in practice. As such, Australian operators have limited certainty as to what they (and others) can do now, or will be able to do in the future.\textsuperscript{1110}

\textit{Impartiality:} As set out above, although \textit{CASR Part 101} outwardly creates a known framework, the actual requirements are unclear and UAS certification relies on discretionary, case-by-case assessments or other approvals by CASA.\textsuperscript{1111} It is also apparent that certification requirements are difficult for CASA to enforce in that ‘Small’

\begin{footnotesize}
\textsuperscript{1106} \textit{CASR Part 101} reg 101.280.
\textsuperscript{1107} Coyne, above n 143, 4.
\textsuperscript{1108} \textit{AAIF Report}, above n 11, 6.
\textsuperscript{1109} Coyne, above n 143, 4, 5.
\textsuperscript{1110} See Coyne, above n 143, 3.
\textsuperscript{1111} \textit{AAIF Report}, above n 11, 6.
\end{footnotesize}
UAS frequently operate over ‘populous’, residential areas presumably without airworthiness certification (or other approval). As noted above, it appears that for the most part, CASA relies on the issuance of operational approvals as a regulatory basis, rather than on the airworthiness stipulations of CASR Part 101.

Thus there are clear issues with CASR Part 101 when considered against the requirements for comprehensiveness, and workability. Given the effects of the limited explanation and exploration by CASA as to the costs, benefits and risks involved with UAS operations when preparing CASR Part 101, the fact that there is confusion as to the first 3 key decisions is amplified upon consideration of the rules that apply. For example, why should all UAS-AC over 150kg be required (at least overtly) to obtain certificates of airworthiness in a manner comparable to conventional aircraft (which are much heavier than 150kg). Thus although CASR Part 101 is commendable for having been published and available for use and debate at a comparatively early time, CASA has essentially conceded that CASR Part 101 is not properly explained, was not developed so as to take account of cost/benefit or risk analyses, has not created certainty for business, and generally does not comply with the rule of law principles.

The use of the above example illustrates the way in which an understanding of legal classifications as part of a broader sphere of thought can assist in providing a means to analyse existing classifications of UAS.

1112 Leaving aside whether such operations may have an Operator’s Certificate or an Area Approval the difficulties in ensuring safety are apparent from numerous incidents involving crashes of small UAS: see above at Chapter III.D.3.
1113 Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 27.
1114 See generally Coyne, above n 143; AAIF Report, above n 11.
IX A WAY FORWARD – APPLYING A LEGAL PERSPECTIVE TO CLASSIFICATION

In the final part of this thesis I would like to expand on the way in which the legal analysis of UAS classification set out above can be used as a framework of reference that can be used as a tool for design and evaluation of UAS classification. A second aim of this final Chapter is to provide some initial conclusions as to future directions for studies of UAS classification that might flow from the use of the framework.

A Development of an Evaluative Tool for Classification

The utility of understanding the task of classifying UAS as occurring at the level of secondary legislation within a regulatory system is that the objectives can be distilled from the primary legislation, and a process guiding the design of the scheme is available by reference to the regulatory process. Taken together, these aspects can be utilised as a general framework of reference against which a UAS classification scheme can be analysed in a preliminary fashion, as demonstrated in Chapter VIII above with respect to the CASR Part 101 scheme. That analysis involves an assessment of the quality of the scheme by reference to the principles of the rule of law, which assist in ensuring the effectiveness of laws through a focus on the design stage. However, as noted above, determining the quality of a UAS classification scheme requires clarity as to the benchmarks that are applicable.\textsuperscript{1115} The benchmarks relevant to evaluation can also be used as a guide to design – purpose informs both the design and evaluation of a classification scheme.\textsuperscript{1116}

The framework of reference provided by the regulatory system concept is useful in order to properly situate the relevant technical arguments and to frame these arguments against the critical legal considerations. In that regard, the legal considerations can provide general guidance as to what is required; that guidance is more easily applied in some cases, particularly those involving legal drafting issues such as determining whether

\textsuperscript{1115} Baldwin, Cave and Lodge, \textit{Understanding Regulation}, above n 259, 76. This approach is consistent with the observations of Giemulla in relation to the use in legal reasoning of general principles in situations where there is an absence of guidance to specific legal problems, including in the aviation law context: Giemulla, ‘Sources and Structure’, above n 835, 74.

\textsuperscript{1116} Brennan, above n 470, 214.

203
clarity, simplicity, and consistency are achieved. In other cases, such as determining whether the rules ‘make sense’ to industry or are economically feasible, the relevant benchmarks cannot so easily be provided by recourse to legal knowledge alone. In either case, the framework of reference produced by the regulatory system concept can be used to collect, analyse and vet the state of knowledge in relation to the 4 key decisions within the UAS regulatory field. With continued debate, this framework can then be refined into a set of more specific benchmarks, which is likely to be a process that occurs simultaneously with the refinement of arguments; that is, development of the framework and the arguments can occur together.

I have set out in Table 30 below how this process can be visualised. The table takes one of the key decisions – the decision relating to the selection of criteria – in order to show graphically how the rule of law principles and the statutory objectives to be fulfilled can be used to guide discussion of the pros and cons of each. The rule of law principles are set out in the left column, and the statutory objectives are set out across the top row. Within the matrix created, I have set out in adjacent columns two competing, generic proposals for the selection of classification criteria – a mass criterion such as that proposed under CASR Part 101 (labelled Proposal 1) and an alternative risk metric criterion (labelled Proposal 2).

I have collected the arguments for and against the use of the respective criteria amongst the technical literature and collated these arguments within each cell. These arguments are then weighed (solely for the purposes of illustration) against each of the rule of law principles in each of the 5 rows. I have then used a colour coding/ranking system to indicate the degree to which the competing criteria meet the rule of law requirements (or not).

---

1117 See Chapter V.C.2 above (and Appendix 1 below) in relation to the origin of each of the arguments set out in the matrix. These bullet points are not intended to convey the full substance of complex and ongoing debate, nor to suggest correctness; rather they are used to illustrate the function and utility of the proposed framework.
### Table 31: Illustration of Basic Framework of Reference Constructed from Statutory Objectives, Rule of Law and Technical Opinions drawn from UAS Literature

<table>
<thead>
<tr>
<th>Principle</th>
<th>Comprehensive (principle 1)</th>
<th>Workable (principle 2)</th>
<th>Transparent (principle 3)</th>
<th>Stable (principle 4)</th>
<th>Impartial (principle 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposal 1: ‘Mass Criterion’</td>
<td>Proxy for no. of passengers and other safety criteria</td>
<td>Relatively user-friendly, can be ascertained by users easily</td>
<td>Can be expressed easily</td>
<td>Mass (MTOW) itself not likely to change from flight to flight</td>
<td>Lends itself to fixed breakpoints, less grey area</td>
</tr>
<tr>
<td></td>
<td>Loose correlation with other criteria</td>
<td>Consistent with existing regulation</td>
<td>Doesn’t directly explain differences in treatment in accordance with safety</td>
<td>Likely that new mass classes will emerge over time</td>
<td>Enforcement likely to be simpler</td>
</tr>
<tr>
<td></td>
<td>Describes UAS in terms of only one attribute</td>
<td>Doesn’t align readily with UAS safety objectives</td>
<td>Some correlation with cost/benefit analysis</td>
<td>May involve hidden biases where mass not directly linked to risk</td>
<td>May involve hidden biases where mass not directly linked to risk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inflexible/infeasible as not tailored to operations</td>
<td>No direct correlation with risk analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposal 2: ‘Risk Metric Criterion’</td>
<td>Accounts for multiple attributes relevant to safety</td>
<td>More complex, involves numerous calculations, not easy to ascertain for users</td>
<td>More difficult to express differences in treatment explained by reference to safety</td>
<td>Risk profiles likely to change according to mission</td>
<td>Doesn’t easily correlate to fixed breakpoints, more grey area</td>
</tr>
<tr>
<td></td>
<td>More direct relationship with actual risks</td>
<td>Not aligned with classification of conventional aircraft</td>
<td>Some correlation with cost/benefit analysis</td>
<td>Can be tailored for degree of risk/harm to construct a flexible, modular scheme</td>
<td>Enforcement more complex as complex calculations to be performed etc.</td>
</tr>
<tr>
<td></td>
<td>Better connection between ‘type’ and ‘treatment’</td>
<td>Aligns with UAS safety objectives</td>
<td>More direct correlation with risk analysis</td>
<td></td>
<td>Hidden biases still possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Offers flexibility due to tailoring to mission</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 31: Illustration of Basic Framework of Reference Constructed from Statutory Objectives, Rule of Law and Technical Opinions drawn from UAS Literature
For instance, amongst the technical literature, certain benefits are said to arise from the use of a mass criterion in certifying UAS due to its simplicity and familiarity, and its correspondence with the general level of risk involved with the operation of UAS-AC of differing types. Other work has suggested that mass ought not be favoured because the mass of a UAS-AC does not alone explain the risks involved with a given UAS. In favour of a risk metric, it is said that such measures can explain risk by reference to multiple factors (mass, speed, frangibility etc.) and thereby ought to be used in classifying UAS. Weighing these arguments against the requirement for comprehensiveness (as explained above), I have coded the criteria as ‘Medium’ and ‘High’ respectively. Of course, whether or not mass does or doesn’t adequately define risk is an issue for the technical sources. The framework, however, can provide some resolution as to whether the approaches in question are ‘workable’ or otherwise. Further, the meaning of ‘risk’ in its statutory context (and whether ‘risk’ is actually the relevant term or requirement) is an issue to which legal sources can contribute in the framework. In that regard, further analysis of the legal issues must be undertaken, including in relation to the precise place of UAS within the Chicago Convention system.

The above of course is just an illustration of the way that rule of law principles may be used to create a framework of reference for decision-making. The above example only covers one of the 4 key decisions, all of which will need to be investigated. In that regard, two ‘generic’ proposals are evaluated in a preliminary fashion. In actual use of the matrix, specific examples would be used which will display different results than the general proposals utilised above. For instance, Dalamagkidis, Valavanis and Piegl’s proposals could be compared with those of Clothier et al, and subjected to more intensive analysis.

1118 See Chapter V.B.2 for further details.
1119 See Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50, 514; Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111, 323; AAIF Report, above n 11, 8; Clothier et al, Definition of Airworthiness Categories, above n 3, 7; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 14; Maddalon et al, Considerations of Unmanned Aircraft, above n 49; Fraser and Donnithorne-Tait, above n 211, 14 [4.2.3].
1120 Clothier et al, Definition of Airworthiness Categories, above n 3, 7; AAIF Report, above n 11, 8; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 6, 14, 16; Palmer and Clothier, above n 36, 241.
1121 See the approaches of AAIF, Clothier et al, Dalamagkidis, Valavanis and Piegl, Fraser and Donnithorne-Tait, Weibel and Hansman. These approaches are outlined in Chapter IV. See generally Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 14, 15.
by reference not just the final tabulated scheme itself, but also via a critique of the purposes, methods and structures that underpin the 4 key decisions.

In the present example, the commentary against each of the rule of law principles is derived or extrapolated from the discussion of the current approaches in Chapter IV, and the various pros, cons and desiderata stated therein. Naturally, the above example relies heavily on the conclusions made by more qualified persons studying the technical aspects of classification. As such, the framework set out above should be construed as an example only. The broader utility of the framework is that it permits consideration and debate in relation to vital, technical topics within a legal framework so as to ensure as far as possible that the result is valid and effective from a legal perspective. Work in the technical fields can continue to seek better answers to the many existing questions; naturally progress will not be linear and will still involve subjective preferences for one proposal or another. For instance, one could foresee arguments over which proposal was ‘more workable’ or ‘more feasible’ and perhaps certain statistical measures would be developed in an effort to mathematically determine the answer. It may also be that legal guidance has some capacity to resolve competition between the rule of law principles, for instance it is often thought (at least in Australia) that that law prefers certainty over other considerations, even at the expense of concepts such as ease of use.1122 However, useful gains may be made by considering, within this framework, conclusions in the technical field as to which characteristics or ‘factors’ of UAS are most relevant to safety such as via the survey of approaches conducted by Clothier et al and NASA,1123 and this information can be used to translate progressive technical (and economic) knowledge into written law.

B General Conclusions and Future Directions for Study

The above considerations give rise to some general conclusions flowing from the review of the current approaches and the initial framework of reference discussed above. First, this thesis noted the interrelationship between purpose and the other facets of a

1123 See Palmer and Clothier, above n 36, 7; Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 13.
classification scheme. The relevant purposes to be achieved by a classification of UAS needs to be defined with greater precision and in a manner that can be agreed upon by legal and technical sources. It is notable that there is growing recognition of the connection between classification and risk assessment amongst the ongoing regulatory work. For instance, EASA stated that

keeping rules proportionate to risk is easier said than done. The difficulty will be to come up with a classification of RPAS operations so the rules and procedures can be tailored to the risks. To each category of risk would then be associated with a regulatory regime, so that the rules could range from very light touch operation based rules at one end of the risk scale, to a more comprehensive approach based on the rules and procedures from manned aviation at the other end of the scale.\textsuperscript{1124}

The correlation between the statutory objectives (safety and economic) and the role of classification is clearer here, as contrasted with the CASA approach in \textit{CASR Part 101} outlined above, which implicitly recognises the importance of ‘categorisation’ but without formally considering its role. This is an issue being considered more closely in CASA’s revision of \textit{CASR Part 101}.\textsuperscript{1125} In that regard, NASA’s consideration suggests ‘the role of classification… is to facilitate a standards-based approach to airworthiness certification of UAS, by providing a descriptive framework for grouping together UAS with similar risk characteristics that would then be held to similar airworthiness standards.’\textsuperscript{1126} As set out by Brennan, it is critical to obtain a clear statement of purpose in preparing (or evaluating) a classification.\textsuperscript{1127} The developing technical knowledge can then be used to guide the selection of criteria.

Secondly, the most appropriate methods to be utilised need to be agreed. As set out above, often existing proposals do not clearly state the methods used, or alternatively, the connection between the use of a certain method does not clearly align with the regulatory purpose at hand. The potential for the use of inappropriate methods to frustrate the purpose of the classification is obvious – for instance, if arbitrary methods are used in determining the key decisions it is difficult to envisage that this would achieve safe

\textsuperscript{1124} Yearbook 2014, above n 167, 11 (Per EASA).
\textsuperscript{1125} Coyne, above n 143, 4; CASA NPRM 2014, above n 503, 8, 9.
\textsuperscript{1126} Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 4, 6.
\textsuperscript{1127} Brennan, above n 470, 203.
operations, noting that safety can be achieved through clarity.\textsuperscript{1128} Rather, the steps outlined in the regulatory process ought to be followed. Modern regulatory practices often require, for instance, the use of consultation procedures and data-oriented assessments of the risks being regulated and impacts of regulatory change.\textsuperscript{1129} In that regard, the methods used by CASA in preparing its revised regulations through data collection and assessment appear to be an improvement over the arbitrary methods utilised in developing the classification in \textit{CASR Part 101}.\textsuperscript{1130} Precisely how the data collection and analysis can be used to determine the choice of criteria and class boundaries (and translated to written law) needs to be settled.

Thirdly, the structuring of a classification has a significant impact on the overall effectiveness of the scheme. There is a close tie-in between the methods and structures used to construct a classification scheme. For instance, monothetic structures offer a degree of user-friendliness,\textsuperscript{1131} while other more complex structures might be derived on a polythetic basis by which similarity between UAS can be observed across a greater number of attributes.\textsuperscript{1132} This may create a classification scheme with a more complex understanding of the relationships inherent in data, and, ideally, homogenous classes that represent ‘real similarities and differences’ that are relevant to safety. However, translating these studies into formal law presents numerous challenges, such as finding a way of representing algorithmically derived clusters in terms of simple words and numbers. These are decisions that cannot be made lightly – ultimately, regard should be had to the regulatory process in order to ensure that best practices are utilised in order to achieve the statutory objective. For instance, guidance concerning the drafting and presentation of rules can be used to guide design or evaluation of the matter. It is possible that clustering algorithms can be used to analyse new classification proposals to test for validity rather than as a direct basis for classifying, such as in the case of Clothier et al.;\textsuperscript{1133} that is to be encouraged but the analytical (rather than regulatory) purposes should be clarified. This information can be incorporated in the framework, for instance showing that a certain

\begin{thebibliography}{99}
\bibitem{1128} Bartsch, above n 259, 147.
\bibitem{1129} See, for instance, the requirements of the OBPR in Australia, outlined under Chapter VII.
\bibitem{1130} See Chapter VIII.3.
\bibitem{1131} Brennan, above n 470, 215.
\bibitem{1132} Ibid.
\bibitem{1133} See, for instance, the approach in Palmer and Clothier, above n 36.
\end{thebibliography}
propose did not align with classes defined on a risk metric basis may be used in
determining whether the proposal is properly ‘justified’ according to the ‘transparency’
principle.

Fourthly, in terms of the key decisions the question of criteria requires serious study.
Taking account of the statutory objectives, there appears to be a growing acceptance that
UAS ought to be classified on a basis that correlates with risk.\textsuperscript{1134} The question of the
characteristics of UAS that most accurately describe the risks involved with UAS
operations is one to be resolved by technical input. However, it is also important to
consider how given criteria correlate with economic considerations and the need to
harmonise aviation laws, as well as other issues involving whether particular criteria make
the scheme too complex, inaccessible etc. There are also difficulties associated with the
fact that the risks of UAS are influenced by external factors such as populations overflown
in a way that does not occur for conventional aviation. Further consideration should be
given to whether it is necessary (or possible) to expand the classification across 3
dimensions (aircraft, pilot, airspace) in order to cover the full gamut of considerations, in a
way similar to that proposed by Clothier et al.\textsuperscript{1135} NASA suggests that such approaches are
appealing but fraught with difficulty.\textsuperscript{1136}

These issues of significant structural issues have a spill-over effect in terms of the other
key decisions. These decisions should also be scrutinised according to the above
framework in order to promote resolution of issues concerning, for instance, the
arguments that existing class boundaries found in conventional aviation are unlikely to be
appropriate for UAS regulation and that alternative (or more) boundaries based on risk
assessments are more appropriate. In that regard, further investigations will need to be
made in relation to the historical genesis behind existing boundaries, but there is no reason
to believe that the rule of law principles could not accommodate such arguments. From a

\textsuperscript{1134} See especially Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8; Hayhurst et al, \textit{Review of
Current and Prospective Factors}, above n 214; This is also evident amongst the more recent approaches
taken by regulators: see the \textit{CASA NPRM 2014}, above n 503, \textit{FAA NPRM}, above n 147; \textit{ConOps Proposal},
above n 171.
\textsuperscript{1135} Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 883. Note also the approach
outlined in the \textit{BDLI/UAV Dach Report}, above n 42 (though beyond the scope of this thesis to analyse).
\textsuperscript{1136} Maddalon et al, \textit{Perspectives on Unmanned Aircraft}, above n 8, 13 citing DeGarmo, above n 42; See
also Maddalon et al, \textit{Considerations of Unmanned Aircraft}, above n 49, 2.
practical perspective, the decisions relating to class designations and the applicable rules will be highly dependent on reaching consensus on the first two decisions. Ultimately, the status of UAS regulation is such that the evolving risk knowledge will likely shape all aspects of classification, thereby essentially requiring a complete overhaul of the initial approaches to classification found in early regulation such *CASR Part 101*. 
X SUMMARY

This thesis began by observing the similarities faced by the writer Fearnley in his consideration of the ‘best’ McLaren F1 cars and the task faced by aviation safety regulators as they attempt to sort through numerous proposals for the classification of UAS. It may seem an odd comparison. Yet the fundamental difficulty faced in both tasks is the same: how does one choose the ‘best’ of anything? The answer to the question will be heavily dependent on the context in which the question is asked and the criteria that are relevant to the determination. To Fearnley, as a motorsport enthusiast, the question was multi-faceted and required consideration of the criteria that might be relevant, necessitating the need for a framework of reference against which an assessment could be undertaken. However, as Fearnley observed, answering questions of this kind will, perhaps inescapably, encounter the need for subjective decisions to be made notwithstanding efforts to adhere to ‘objective’ means. The reference framework therefore had both its uses and its limitations. These are familiar issues in the study of UAS classification.

This thesis has explored the many factors at play in the regulation of UAS and investigated the challenges inherent in classification, arriving at a similar to conclusion to Fearnley. Of course, as a question in which legal rights and obligations are at stake, there are practical consequences to the assessment. In that regard, the need for an acceptable classification of UAS has been cited as particularly problematic, and at the same time recognised as a critical part of the regulatory infrastructure. Given that classification represents both a problem and a solution in relation to UAS certification, the issue needs to be resolved as a matter of priority.

The reality is, though, that UAS classification has been recognised as an important legal issue for the better part of a decade and yet this difficult issue remains unresolved. Though progress has been made, consensus remains elusive. Part of the reason is that most approaches to date have not sought to analyse the question from a legal perspective. As such, current approaches to classification do not acknowledge that UAS classifications

---

1137 See Plucken, above n 46, 137.
(when encoded in regulation) are laws, and that they can be evaluated against accepted benchmarks developed to evaluate the quality of laws. Without these general benchmarks to use as a guide, proposals have proliferated without an authoritative means of evaluating the quality of any particular proposal. This lack of an accepted classification scheme for UAS – as a fundamental step in creating regulation – affects the commercial uptake of the technology and regulatory progress.

Chapter II of this thesis investigated the interplay between unmanned aviation and the law. In particular, the historically sporadic development of UAS technologies for use in numerous roles (civil and military), combined with the near-limitless potential applications now on offer, leads to difficulties in defining the technology and agreeing a typology for UAS. Nonetheless, it remains a regulatory imperative to both control the proliferation and use of UAS to ensure safety; this has led to the growth of the global regulatory agenda for UAS. But to date that growth has only really sought to restrict UAS rather than offer long-term and economically viable solutions. Rather, UAS continue to be treated – even under recent legislation – as a fundamentally different technology that is to be exempted from the usual requirements. In that regard, the regulatory agenda for UAS is replete with observations of the need for a pathway enabling the integration of UAS into the existing system in the true sense.

Chapter III examined the ways in which UAS confront rather conform to the existing safety system. In particular, the role that classification plays in the challenge of developing a certification regime for UAS is examined. The issue as to certification is one that arises in the regulation of UAS by simply observing the way that the safety system currently operates for conventional aviation. The existing system has developed over the course of time by requiring conventional aircraft to demonstrate compliance with evolving certification requirements; as technology has improved, so too has the safety expectation increased. Thus, airworthiness certification has provided the pathway for manufacturers and operators to follow in order to gain access to public airspace: rigorous safety testing, developed over the years and proven in action, has provided an assurance that particular aircraft are safe for operation. No such system exists for UAS; existing requirements

---

1138 AAIF Report, above n 11, 2; Michaelides-Mateou and Erotokritou, above n 27, 113.
cannot logically or practically be applied to UAS, and considerable doubt remains as to precisely what shape the certification regime for UAS ought to take. For the purposes of this thesis I analysed the problematic issues of certification as involving a lack of agreement as to the proper basis for certification (prescriptive or safety target), a lack of accepted means of accessing the risks of UAS operations, limited knowledge of the effects of regulation on the market, and the absence of harmonisation or concordance between the approaches taken in different jurisdictions. With this in mind, the de facto stance is to require that UAS demonstrate ELOS. Having no means of actually achieving that de facto standard other than by submitting to case-by-case assessment and operational restrictions, routine (and legal) commercial operations are hindered or delayed.\textsuperscript{1139}

Chapter IV focused on the issue of classification as a logical starting point in tackling these issues. For instance, it is clear that questions of classification are entwined with – and causing – several of the regulatory challenges as issues concerning the appropriate ‘types’ of UAS for certification pervade each of the 4 challenges noted above. Indeed there is difficulty in even approach the topic of certifying UAS without some understanding of these types. In that regard, there appears to a singular point of consensus evident in the UAS literature that there can be no ‘one-size-fits-all’ approach. Whatever form the certification regime for UAS might take, it must ensure that the degree of regulatory stringency is tailored across the extremely diverse fleet of UAS-AC. Numerous approaches to classification have therefore been developed amongst the regulatory, technical and legal sources examining the topic of UAS certification. The primary purpose of Chapter IV was to provide an overview of these approaches so that their points of commonality and difference could then be illuminated. It was not possible to comprehensively cover the full breadth of relevant work in this thesis. Chapter IV therefore drew upon selected work – past and present – to demonstrate the developments that have occurred in the area since classification was first identified as a complex and critical issue in 2004.

This fact – the continuing debate over classification after the passage of decade – was considered in Chapter V. It is notable that there remains a lack of consensus in relation to

\textsuperscript{1139} Clothier, Fulton and Walker, ‘Pilotless Aircraft’, above n 22, 1004; AAIF Report, above n 11, 6.
the core aspects that determine the construction of a classification scheme. The current approaches reviewed in Chapter IV were analysed against these core aspects with the result that methods and structures utilised in the current approaches differ widely, though there is a discernible trend towards connecting the classification exercise with the study of the risks of UAS, and also in terms of using mathematical and statistical processes to discern classes of similar UAS. Nonetheless, and critically, the current approaches do not often define the purpose of the classification exercise with specificity. This has a number of effects on the creation of the scheme. Commonly, classification proposals proceed on the basis that a classification of UAS is self-evident or ascertainable by empirical means, rather than an aspect entirely inherent to the regulatory action that requires a rigorous study. This approach was encountered more commonly in the early 2000s when UAS technologies were only just emerging as a legitimate sector of aviation endeavour. The trend towards increasingly sophisticated approaches to classification has paralleled the increasing sophistication of UAS technologies over time.

Nonetheless there remain vast discrepancies when the current approaches are viewed in terms of the 4 key decisions to be made when a classification scheme is to be reduced to writing as law: the choice of criteria for distinguishing one UAS from another, the creation of class boundaries, the naming of classes, and the construction of rules pertaining to each class. One reason for this is that there is no agreement as to precisely which ‘traits’ are desirable in a UAS classification scheme. For instance, there are at least 23 traits identified in the current thinking as representing desiderata for UAS regulations or classification. I therefore concluded in Chapter V that there is a tangible need for a framework of reference for UAS classification. On my analysis, this array of desiderata arises from the fact that most of the current approaches are derived from technical perspectives. These perspectives may be entirely valid given the multidisciplinary nature of the regulatory endeavour. However, whilst there is a lack of authoritative guidance or accepted principle on which to proceed (which I argue can be derived from a legal perspective) it is difficult to see how these differences can be reconciled.

These ideas were developed further in Chapter VI. The absence of consideration of UAS classification from a legal perspective means that useful tools that can be used to analyse
regulatory context and guide design have been omitted from the field of work. Perhaps more fundamentally, the current approaches do not recognise that a UAS classification, when reduced to written law, effectively becomes law. The fact that a certification regime for UAS is needed, and this regime is to be enshrined in law as secondary legislation, calls for the application of a legal perspective. This perspective is distinct from other, technical perspectives, and the absence of legal consideration represents a notable void in the study of classification. With that in mind, an interface is needed in order to apply a legal lens to the expansive field of useful technical work that has already occurred. As lawyers are accustomed to analysing written laws, rather than mathematical and statistical formulae, I have utilised guidance from the related fields of sociology and criminology (where practitioners more readily deal directly with classification schemes in a scientific or technical setting) to form a template for reviewing the technical work. The work of Brennan and Starr in explaining classification in terms of its core aspects provides the interface and the synergies with legal rulemaking are apparent. The classification can thus be translated into familiar legal terms.

Viewed as an exercise in developing law, useful guidance can be obtained from understanding the place of the proposed certification regime within the broader ‘regulatory system’. Accessing this guidance is the topic of Chapter VII. As a starting point, the work of Salembier is used to explain that a regulatory system is comprised of a regulatory regime and regulatory processes. That is, the legal system creates both substantive rules, designed to guide conduct towards the desired ends of the government, as well as ‘meta-rules’ which guide the creation of the substantive rules. Both aspects are influence the shape and effectiveness of the regulatory system on the whole. On the basis that the UAS certification regime is an issue for secondary legislation, the guidance that can be obtained is two-fold. First, the objectives to be achieved by the certification regime can be determined by analysis of the primary legislation (in Australia’s case, the *Aviation Act*). Second, the rule of law concepts inherent in the regulatory processes provide critical guidance towards ensuring the statutory objectives are met. This understanding can be used to generate the missing framework of reference against which the design and evaluation of UAS classification schemes can be measured.
This is demonstrated in Chapter VIII through a case study of the Australian CASR Part 101 regulations. In that Chapter, the classification scheme within CASR Part 101 is exposed and its componentry analysed against the purposes, methods, structures and key decisions. In particular, the rule of law principles are used as a basis for assessing each of the key decisions. The rule of law principles are designed to improve the quality of regulations in order to attain the objectives of the regulatory system. In that sense, the rule of law principles have the statutory objectives encoded within them. Thus, the classification exercise can be approached as an exercise in lawmaking and vetted against the rule of law principles – which is precisely what would (or should) occur in the ordinary course of regulatory development in Western economies. On that basis the framework of reference has practical utility in understanding the various UAS classification schemes, and in forming initial views as to areas of weakness and strength that are highlighted by the rule of law considerations.

Chapter IX completes this thesis with a series of observations flowing the case study undertaken in Chapter VIII. These conclusions indicate that further work is required to refine the framework of reference, but that progress will be dependent on the adoption of a multidisciplinary approach to classification. Although a legal perspective can provide general benchmarks for improving (and measuring) the quality of regulation, it cannot alone provide a definitive answer to classification. However, the utility of the argument is that the key decisions can be mapped against a set of broadly applicable and authoritative requirements such that competing considerations such as ‘certainty’ and ‘simplicity’ can be fully evaluated and, where necessary, weighed against the statutory objectives. A table is used as an example how each key decision might be vetted against the rule of law principles in order to determine the degree of compliance, and thus provide an indication of the quality of the proposal. By that means, a legal perspective can be used to frame ongoing debate amongst the technical sources and used to guide further study.

In that regard, a word of caution from Brennan’s useful work on classification in criminology could not be more apposite to the problem confronting the integration of important technical knowledge into the legal field – it is worth citing in full:
Cross-disciplinary transfer of methodological concepts can be hazardous. The production of spurious and misleading results is a serious danger. In conducting classification research, an analyst must make many methodological choices. These include such things as the choice of input variables, transformations, similarity coefficients, and a clustering or classification method. Guidance in making many of these decisions is often lacking. For example, there are now over 100 new cluster-analytic techniques available, and there remain many unsolved problems in their use. The critical concepts of ‘cluster’ and ‘similarity’ embedded in these methods have yet to be clearly related to a criminological context. There is no agreement on the best criteria of optimality for clustering or ordination to represent patterns of similarity between objects in a sample with a minimum of distortion. Problems persist in regard to tests of significance for clusters. Yet applied researchers in most fields have not waited for theoretical and mathematical answers to these problems and have aggressively used these techniques. A critical challenge, therefore, is to learn how to incorporate these powerful quantitative techniques into criminology in a manner that solves rather than creates problems.\footnote{Brennan, above n 470, 242.}

Clearly much more work is needed to complete the picture; this work should be completed carefully and progressively. The suggestion in the current approaches that the technical work alone may not be able to resolve all of the questions surrounding the classification of UAS aligns with a similar limitation that is inherent in the legal approach. These of course are not failings but rather opportunities for cross-disciplinary collaboration and constructive debate. Even then, it is unlikely that all doubt can be removed. Rather, it is hoped that the framework of reference presented in this thesis can serve as a rough schematic that can be used as a basis for encouraging the alignment of legal, technical and economic considerations over time as the UAS industry develops and a clearer picture of the regulatory landscape emerges.
APPENDIX 1: SELECTION OF CLASSIFICATION CRITERIA

This appendix provides a reference point for a summary of the technical views on the possible criteria for classification. These views are drawn from the current approaches reviewed in Chapter IV.

A  Mass / MTOM / MTOW

Mass is a common discriminator of aircraft for regulatory purposes, and the primary means by which aircraft are differentiated for the purposes of conventional aircraft airworthiness. However, there is little information available as to why this is the case historically. It appears that mass is used to approximate the magnitude of risk as an indication of the size of the aircraft and the number of passengers potentially exposed to harm (essentially as a rule of thumb). Given the lack of passengers with respect to UAS, there is an obvious question as to whether mass is an appropriate criterion for the classification of UAS. Nonetheless it is accepted that the mass of a UAS-AC has a role in UAS classification. Dalamagkidis, Valavanis and Piegl concluded that mass provides a ‘good basis to classify based on… risk’, which can be used to estimate other factors in the risk equation. Fraser and Donnithorne-Tait also note with approval the simplicity afforded by utilising mass as a criterion in classification. However, Clothier et al concluded based on analyses of a large UAS dataset that mass alone may not properly describe the potential harm of a UAS. Clothier et al further concluded that the mass of

---

1141 Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 14; Clothier et al, Definition of Airworthiness Categories, above n 3, 7; see also Dalamagkis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50, 514; Dalamagkis, Valavanis and Piegl, ‘Current Status’, above n 111, 343.
1142 However, mass is not the sole means of differentiating aircraft under conventional aviation regulations: See Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 6.
1143 NASA raises the query as to whether the current mass classes are appropriate even for conventional aircraft: Hayhurst et al, Review of Current and Prospective Factors, above n 214, 13.
1145 Mass here refers to the mass of the UAS-AC, not the mass of the UAS (which would include the ground components).
1147 Ibid 514; See also Plucken, above n 46, 101.
1148 Fraser and Donnithorne-Tait, above n 211, 170.
1149 Clothier et al, Definition of Airworthiness Categories, above n 3, 7.
the UAS-AC does not properly describe the diversity of UAS characteristics, nor the safety risks (which require analysis of a multitude of factors).  

**B Kinetic Energy**

Several proposals (for instance, CAA, EASA, Clothier et al, and Fraser and Donnithorne-Tait) refer to the use of kinetic energy measurements of the UAS-AC as a criterion in classification. Kinetic energy is a measure of the force potential of an object in motion at a given point in time, and it is expressed as a function of the object’s mass multiplied by its velocity (essentially). An aircraft’s kinetic energy potential can be estimated by reference to its mass and its estimated or maximum achievable velocity in different flight scenarios. This can provide regulators with an estimate of the maximum force that could be applied to any object struck by the UAS and hence an estimate of the damage that the UAS can cause. This measurement therefore provides additional risk information than afforded by mass alone. The CAA notes that kinetic energy measurement provides ‘an all-encompassing criterion applicable to all aircraft types, is easy to determine and can be readily estimated during the design process.’ The use of such a criterion has precedent in assessing new aviation technologies for the purposes of conventional aviation regulation. However, it appears to be accepted that kinetic energy alone cannot provide all of the necessary information with regard to the damage caused by an accident involving a UAS. Rather more comprehensive measurements

---

1150 See, eg, Palmer and Clothier, above n 36, 14; See generally Maddalon et al, *Perspectives on Unmanned Aircraft*, above n 8, 15, 16.
1151 See, eg, Palmer and Clothier, above n 36, 14; See generally Maddalon et al, *Perspectives on Unmanned Aircraft*, above n 8, 15, 16.
1152 Formerly, under the Light UAV Policy: See Haddon and Whittaker, above n 176.
1153 The EASA approach draws on the earlier work of the UK CAA and the JAA: See the EASA A-NPA, above n 8, 15, 16.
1154 Clothier et al, Definition of Airworthiness Categories, above n 3, 6-9.
1155 Fraser and Donnithorne-Tait, above n 211, 15 [‘Derivation of Small UA Mass Classes’].
1156 Maddalon et al, *Considerations of Unmanned Aircraft*, above n 49, 10.
1157 Clothier et al, Definition of Airworthiness Categories, above n 3, 7; Maddalon et al, *Considerations of Unmanned Aircraft*, above n 49, 10.
involve the shape and frangibility of the construction of the UAS-AC (inter alia).\textsuperscript{1161} Technical views nonetheless suggest that kinetic energy metrics remain a ‘good model’ for risk and fatality estimation.\textsuperscript{1162}

C  Risk Metrics

There is a considerable body of work available in the literature that studies the use of risk metrics in the regulation of UAS by which a better understanding of a full risk profile for a UAS in its operating environment is sought.\textsuperscript{1163} Using these metrics generally involves deriving an equation for calculating the risks of given UAS in certain scenarios as functions of the likelihood or severity of possible accidents. Risk metrics often take account of broader array of factors such as frangibility, aircraft shape and dimensions, lethal area, time of exposure, and sheltering – in addition to mass and velocity.\textsuperscript{1164} By deriving mathematical safety or reliability standards from existing data sources for conventional aircraft, this can then be used to compare a target level of safety with the calculated risks of certain UAS and determine possible airworthiness or operational requirements.\textsuperscript{1165}

These are concepts familiar in the aerospace engineering and risk management circles. However, risk metrics inevitably increase the complexity of the classification scheme,\textsuperscript{1166} for the reason that multiple factors need to be input and assessed. Nonetheless, proponents such as Clothier argue that for the purposes of classifying or certifying UAS, ‘risk cannot be argued with (it’s why regulations are developed)’.\textsuperscript{1167} Such work has undoubted potential in terms of generating a classification scheme, and though there is no consensus

\textsuperscript{1161} See Hayhurst et al, \textit{Review of Current and Prospective Factors}, above n 214, 22.
\textsuperscript{1162} Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50, 511; See also Hayhurst et al, \textit{Review of Current and Prospective Factors}, above n 214, 24.
\textsuperscript{1163} See, eg, AAIF Report, above n 11; Clothier et al, \textit{Definition of Airworthiness Categories}, above n 3; Clothier et al, ‘Airworthiness Certification Framework’, above n 49; Dalamagkidis, Valavanis and Piegl, \textit{Current Status’}, above n 111; Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50; Fraser and Donnithorne-Tait, above n 211; Weibel and Hansman, above n 47.
\textsuperscript{1164} See, eg, Clothier and Walker, \textit{Casualty Risk Analysis}, above n 40.
\textsuperscript{1166} See generally Clothier and Walker, \textit{Casualty Risk Analysis}, above n 40, 4; DeGarmo, above n 42, 2-40.
\textsuperscript{1167} Clothier, above n 53, 17.
on the form and content of the risk model appropriate to that task, risk metric approaches have found a degree of support amongst regulators.\textsuperscript{1168}

D Airspace Categories

Other proposals focus on the way in which UAS will use existing airspace in order to develop a classification scheme.\textsuperscript{1169} For instance, Peterson’s study in 2006 adopted the proposal of the US Office of Secretary of Defense in 2004 that UAS be separated into 3 categories: Category 1 being comprised of ‘model aircraft’ equivalent UAS, which are subjected to restricted, line-of-site operations; Category 2, being equivalent to ‘Ultralight’ or ‘Light Sport’ aircraft and subject to consensus standards of airworthiness and subject to operational restrictions; and Category 3 being effectively equivalent to conventional aviation.\textsuperscript{1170} Support for a closer tie-in between airspace use and airworthiness certification has also been advocated by DeGarmo and Plucken.\textsuperscript{1171} The primary advantage for doing so would appear to be that the risk of mid-air collision can be addressed more directly than in other approaches,\textsuperscript{1172} and that doing so avoids creating new law specifically to address UAS.\textsuperscript{1173}

E Other Possibilities

The above discussion illustrates that there are numerous attributes of UAS that could conceivably be relevant for the purposes of classifying UAS. Without covering the full gamut of possibilities,\textsuperscript{1174} the relevance of airframe manoeuvrability metrics,\textsuperscript{1175} operating

\textsuperscript{1168} Yearbook 2014, above n 167, 9 (per EC), 11 (per EASA); See also the approaches evident in the CASA NPRM 2014 and the FAA NPRM reviewed above: Chapter IV.D.1.

\textsuperscript{1169} Although the scope of this thesis focuses on ‘technical airworthiness’ rather than ‘operational airworthiness’ (as explained in AAIF Report, above n 11), airspace usage is discussed here as a point of comparison, given the overlap between the different pillars of regulation when it comes to UAS: AAIF Report, above n 11, 7.

\textsuperscript{1170} See Peterson, above n 5, 596, citing Office of Secretary of Defense (US), above n 114, 11–14.

\textsuperscript{1171} DeGarmo, above n 42, 2–40; Plucken, above n 46, 101.

\textsuperscript{1172} Plucken, above n 46, 101; The JAA/Eurocontrol Report, above n 59, 16 notes that this issue is not traditionally addressed by airworthiness certification and is an air traffic management issue, rather than a certification issue.

\textsuperscript{1173} Peterson, above n 5, 598.

\textsuperscript{1174} Note that Korchenko and Illyash has identified 16 possibly relevant attributes: see Korchenko and Illyash, above n 652, 29 - 31; Maddalon et al identifies 20: See Maddalon et al, Considerations of Unmanned Aircraft, above n 49, 8-13.

\textsuperscript{1175} See Cotting, above n 377; See also Maddalon et al, Considerations of Unmanned Aircraft, above n 49, 9.
range, and the autonomy level of the system would also appear to play a part in the full risk profile of a UAS.

---

1176 See Maddalon et al, *Considerations of Unmanned Aircraft*, above n 49, 10.
1177 Ibid 12.
1178 DeGarmo, above n 42, 2-40; See Maddalon et al, *Considerations of Unmanned Aircraft*, above n 49, 10.
APPENDIX 2: DEFINITION OF CLASS BOUNDARIES

A  Adopting or Translating Boundaries from Manned Aviation Regulations

Certain proposals incorporate or adopt boundaries evident in existing regulation, for instance, mass boundaries at 25kg, 150, and 600kg. Given the unique nature of UAS, it must be questioned as to whether these boundaries are appropriate for UAS. As set out above, there is limited analysis of the historical reasoning processes underpinning some of the existing mass boundaries. The following can be ascertained in general terms:

(a) The boundary at 25kg is commonly drawn from the upper weight limit of model aircraft under a number of regimes, though in Canada the limit is 35kg. There is little further information as to how any of these figures were derived and legislated historically. Fraser and Donnithorne-Tait noted in their research that they were aware of no such study.

(b) The 150kg boundary is widely adopted and appears to have been derived from the requirements of EC regulations by which the EASA jurisdiction is delimited in Europe. Kaiser explains the rationale for the specification of the boundary relating to ‘the physical consideration that objects with low mass and velocity have only a limited destructive impact potential’. The JAA Eurocontrol Report suggests that the figure was derived from a review of international data. Fraser and Donnithorne-Tait note that the figure lacks justification on any risk-related

1180 See the approaches of CASA, FAA, TC, ASTM reviewed in Chapter IV.D. See generally Dalamagkidis, Valavanis and Piegl, ‘Current Status’, above n 111; Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50; Fraser and Donnithorne-Tait, above n 211.
1181 See the ASTM International, above n 528 approach (now withdrawn) reviewed in Chapter IV.
1182 Palmer and Clothier, above n 36, 1; Hayhurst et al, Review of Current and Prospective Factors, above n 214, 13.
1183 See Fraser and Donnithorne-Tait, above n 211, 159-160 for their analysis of the genesis of the 25kg and 150kg.
1184 See generally Fraser and Donnithorne-Tait, above n 211, 160.
1185 Office of Civil Aviation Standards (Canada), above n 164, 3.
1186 Fraser and Donnithorne-Tait, above n 211, 160.
1187 See the approaches of EASA, CASA, TC, ASTM reviewed in Chapter IV.D; See Fraser and Donnithorne-Tait, above n 211, 157, 160. See in relation to the EC regulation, Kaiser, ‘UAVs and Their Integration’, above n 46, 170.
1189 JAA/Eurocontrol Report, above nn 59, 1089.
basis, and the EC itself recently stated that the 150kg demarcation is ‘questionable’ and doesn’t provide for coherent safety policy; \(^{1191}\)

(c) The 600kg boundary sometimes encountered in the UAS literature derives from the upper mass limit for light sport aircraft standards. \(^{1192}\) However, the historical and regulatory reason for specifying that figure does not appear to have been closely examined in the context of UAS regulations.

Although the adoption of class boundaries from existing regulations may theoretically further the goal of harmonisation, there is a danger that doing so will incorporate into the adoptive scheme a degree of ambiguity where the relevant reasoning process underlying the boundary is opaque.

B Natural Tendency

Several of the current approaches reviewed seek to establish classes on the basis of ‘observing’ groups or clusters of UAS that are said to occur ‘naturally’; that is, that the relevant data relating to UAS shows a natural tendency towards certain groupings. The claimed advantage of this approach is that classes are structured around groups that actually exist, rather than by being arbitrarily imposed, and thereby possibly offering additional rigor or objectivity. \(^{1193}\) Tendencies in the data may be observed visually by plotting UAS characteristics (mass, speed, altitude for instance) so as to identify apparent groupings of UAS with the eye. This kind of classification method is apparent in the approaches of EASA, \(^{1194}\) Eurocontrol/IABG, \(^{1195}\) and Weibel and Hansman, \(^{1196}\) and a similar visual estimation (of a sort) appears to have been made Dalamagkidis, Valavanis and Piegl. \(^{1197}\) Visual processes ought to be approached with some caution as human beings do not display particularly good judgment in that regard when presented with a large

\(^{1190}\) Fraser and Donnithorne-Tait, above n 211, 158, 177.
\(^{1191}\) Yearbook 2014, above n 167, 9 (Per EC).
\(^{1192}\) Fraser and Donnithorne-Tait, above n 211, 163; Dalamagkidis, Valavanis and Piegl, ‘On Unmanned Aircraft’, above n 50, 510.
\(^{1193}\) See, eg, Clothier et al, Definition of Airworthiness Categories, above n 3, 8–10.
\(^{1194}\) EASA A-NPA; See Maddalon et al, Perspectives on Unmanned Aircraft, above n 8, 30.
\(^{1195}\) Eurocontrol/IABG Report, above n 488, 21.
\(^{1196}\) Weibel and Hansman, above n 47, 36-39.
number of samples: for instance it would be easier to visualise groupings when only 2 attributes (thus, two dimensions) are used, (noting that the use of fewer dimensions may result in the classification containing less information).

Some approaches therefore use computer algorithms to assess a UAS dataset for data exploration purposes, as well as to report or create clusters based on more complicated multi-factor analyses. An example can be found in the work of Clothier et al, undertaken with a view to achieving a ‘more objective approach’, and ‘meaningful groupings’, and the ability to discern classes where there are no ‘easy’ lines of demarcation. Clothier et al notes, however, that there are natural limitations in relation to the use of data tools in the development of a classification scheme, such as the need for current and accurate data. Additionally, some level of adjustment may be needed to translate the results of a clustering process (which may not produce disjoint classes) into a useful, written classification scheme.

C The Related Question: How Many Classes?

Determining the relevant class boundaries naturally involves the question as to how many classes ought to be used. Some have observed that classification schemes comprised of a higher number of classes provide additional ‘resolution’, which I understand to be the ability to gain a ‘clearer picture’ of the types of UAS within each group or a greater reflection of the variety of UAS. This is a particular issue for smaller UAS-AC where the need for resolution derives from the particular diversity of UAS-AC designs and

1198 See Brennan, above n 470, 203.
1199 See, eg, Clothier et al, Definition of Airworthiness Categories, above n 3, 6; Palmer and Clothier, above n 36, 3.
1200 See, eg, Clothier et al, Definition of Airworthiness Categories, above n 3, 6–8.
1201 Clothier et al, Definition of Airworthiness Categories, above n 3, 7.
1202 Clothier, above n 53, 14.
1203 Palmer and Clothier, above n 36, 14.
1204 See generally Clothier et al, Definition of Airworthiness Categories, above n 3, 6-8.
configurations at lower mass.\textsuperscript{1206} In that sense there is an apparent need to ‘reflect the reality of the multitude of UAS types and capabilities’.\textsuperscript{1207}

It has been said that the minimum number of classes is zero, and there is no upper limit.\textsuperscript{1208} For example, if 100 UAS were to be included in a scheme, greater ‘resolution’ would be achieved as the number of classes used approached 100 (at which point each UAS would have its own class).\textsuperscript{1209} In that regard, the degree of ‘tailoring’ or ‘flexibility’ for individual UAS will also increase.\textsuperscript{1210} Therefore, the number of classes used will have a significant influence on the classification structure,\textsuperscript{1211} and increasing numbers of classes will naturally complicate the scheme.\textsuperscript{1212} At some point this will make the scheme unworkable or impractical.\textsuperscript{1213} For instance, if a regulator must decide which of 100 possible classes that a particular UAS belongs to, the scheme will be inefficient to use. The challenge therefore appears to be to find the ‘optimal’ number,\textsuperscript{1214} which will likely involve the weighing and balancing of all of the above considerations.\textsuperscript{1215} Ultimately, there is no ideal number of categories, the number will be selected based on a somewhat subjective balancing act.\textsuperscript{1216} Notwithstanding the comprehensive studies undertaken, Clothier et al assess that the number of categories is more likely to be determined by the context of the problem (i.e. broader subjective trade-offs…), rather than by the mathematically optimal solution… [it is] unlikely that this process will ever be reduced to a purely mathematic approach.\textsuperscript{1217}

\textsuperscript{1206} Yearbook 2014, above n 167, 61 (Per EASA); In that regard, see the sUAS ARC Report outlined in Chapter IV.D.1 above in relation to potential classes of UAS at the lower end of the mass spectrum (less than 25kg): sUAS ARC Report, above n 521, 22.
\textsuperscript{1207} Plucken, above n 46, 79.
\textsuperscript{1208} Clothier et al, Definition of Airworthiness Categories, above n 3, 4.
\textsuperscript{1209} See Clothier et al, Definition of Airworthiness Categories, above n 3, 4; See also Clothier et al, ‘Airworthiness Certification Framework’, above n 49, 879.
\textsuperscript{1211} Ibid.
\textsuperscript{1212} Ibid 879; Clothier et al, Definition of Airworthiness Categories, above n 3, 4, 8; Clothier et al notes this is undesirable: Palmer and Clothier, above n 36, 14.
\textsuperscript{1214} Ibid 879; Clothier et al, Definition of Airworthiness Categories, above n 3, 4, 8.
\textsuperscript{1217} Clothier et al, Definition of Airworthiness Categories, above n 3, 9, 10; Note this is consistent with Fearnley’s observations set out in the Preamble to this thesis. See Fearnley, above n 1.
## APPENDIX 3: GLOSSARY

<table>
<thead>
<tr>
<th>Term</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apodosis</td>
<td>The part of a rule that expresses the consequence or substance of the rule</td>
</tr>
<tr>
<td>Certification Regime (or Framework)</td>
<td>The formal, legal structure for the airworthiness certification of UAS by which types of UAS are defined and general standards allocated</td>
</tr>
<tr>
<td>Class Designation</td>
<td>The name given to a class of objects</td>
</tr>
<tr>
<td>Conventional Aircraft</td>
<td>A manned aircraft whereby the pilot controls the aircraft from on-board (for instance a typical Cessna, Boeing or Airbus)</td>
</tr>
<tr>
<td>Conventional Aviation</td>
<td>The activity of designing, developing and using of aircraft as commonly understood by reference to manned aircraft whereby the pilot controls the aircraft from on-board</td>
</tr>
<tr>
<td>Core Aspects</td>
<td>The purposes, methods, structures and key decisions involved in designing a classification scheme</td>
</tr>
<tr>
<td>Criteria</td>
<td>The characteristic(s) relevant to the creation of classes</td>
</tr>
<tr>
<td>Desiderata</td>
<td>The desirable traits or features of a classification scheme</td>
</tr>
<tr>
<td>Folk Classification</td>
<td>An everyday classification commonly utilised in society but without necessarily being formalised</td>
</tr>
<tr>
<td>Framework of Reference</td>
<td>A conceptual structure against which the quality of a classification scheme for UAS can be measured; a set of fixed authoritative reference points that can guide discussion</td>
</tr>
<tr>
<td>Term</td>
<td>Meaning</td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Key Decisions (also called ‘preferments’)</td>
<td>The 4 primary or high level decisions to be made when constructing a classification scheme for UAS certification – the selection of the relevant characteristic(s) of drones; the specification of boundaries to create classes; the names to be applied, and the rules applicable to each created class</td>
</tr>
<tr>
<td>Kinetic Energy</td>
<td>In physics, an object’s kinetic energy is the energy that it possess as a result of its mass and its motion, measured in joules; kinetic energy can therefore be calculated as $E_k = \frac{1}{2}mv^2$</td>
</tr>
<tr>
<td>Mass (or Weight) Boundary</td>
<td>The specification of a certain mass threshold as delimiting the parameter for the membership of a particular class of conventional aircraft or UAS</td>
</tr>
<tr>
<td>Model Aircraft</td>
<td>Unmanned aircraft used for sport/recreation/hobby purposes (usually defined as being below 25kg in MTOW); also referred to as RC aircraft</td>
</tr>
<tr>
<td>Natural Tendency</td>
<td>The observation of ‘naturally’ occurring groups or classes of objects through statistical or mathematical observation and analysis of data</td>
</tr>
<tr>
<td>Official (or Legal)</td>
<td>A classification scheme established by a legal or political system and enforced or endorsed by the State</td>
</tr>
<tr>
<td>Preferments</td>
<td>The 4 fundamental aspects of classification as conceived by Starr, upon which this thesis bases the 4 key decisions</td>
</tr>
<tr>
<td>Primary Legislation</td>
<td>Legislation promulgated by the government or parliament that has primary lawmaking power in a nation</td>
</tr>
<tr>
<td>Term</td>
<td>Meaning</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Protasis</td>
<td>The part of a rule that expresses the condition to be fulfilled</td>
</tr>
<tr>
<td>Regulatory Process (or</td>
<td>The set of rules that improve the quality of rules by ensuring</td>
</tr>
<tr>
<td>meta-rules)</td>
<td>governing the process by which rules are created</td>
</tr>
<tr>
<td>Regulatory Regime</td>
<td>The part of a regulatory system that describes the substantive rules of</td>
</tr>
<tr>
<td></td>
<td>conduct as enacted by the government</td>
</tr>
<tr>
<td>Regulatory System</td>
<td>The complete set of rules – substantive rules and meta-rules – by</td>
</tr>
<tr>
<td></td>
<td>which the government seeks to influence the conduct of a society in</td>
</tr>
<tr>
<td></td>
<td>some way</td>
</tr>
<tr>
<td>Risk Metric(s)</td>
<td>The investigation, measurement or expression of risk in quantified</td>
</tr>
<tr>
<td></td>
<td>form; normally encountered in risk management and safety science</td>
</tr>
<tr>
<td>Secondary (or Delegated)</td>
<td>The more detailed legislation promulgated and usually administered by</td>
</tr>
<tr>
<td>Legislation</td>
<td>a specialist agency under the delegated authority provided for by the</td>
</tr>
<tr>
<td></td>
<td>primary legislation (also known as delegated legislation and subordinate</td>
</tr>
<tr>
<td></td>
<td>legislation, and sometimes, regulation more broadly)</td>
</tr>
<tr>
<td>Scientific Classification</td>
<td>A classification of objects that proceeds on scientific or mathematic</td>
</tr>
<tr>
<td></td>
<td>grounds or for such reasons</td>
</tr>
<tr>
<td>Three Pillars</td>
<td>The three primary ways by which the aviation safety system regulates</td>
</tr>
<tr>
<td></td>
<td>aircraft safety: the regulation of aircraft, airspace and pilot</td>
</tr>
<tr>
<td>Type Certification</td>
<td>The process by which the design of a conventional aircraft is assessed</td>
</tr>
<tr>
<td></td>
<td>by an authority and certified to be safe for production, such that</td>
</tr>
<tr>
<td></td>
<td>multiple aircraft conforming to the certified design can be constructed</td>
</tr>
<tr>
<td></td>
<td>and issued with individual certificates of airworthiness</td>
</tr>
</tbody>
</table>
### APPENDIX 4: ACRONYMS

<table>
<thead>
<tr>
<th>Term</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIF</td>
<td>Australian Aerospace Industry Forum (Australia)</td>
</tr>
<tr>
<td>AGL</td>
<td>Above Ground Level</td>
</tr>
<tr>
<td>AIAA</td>
<td>American Institute of Aeronautics and Astronautics (US)</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials (US)</td>
</tr>
<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
</tr>
<tr>
<td>CAA</td>
<td>Civil Aviation Authority (UK)</td>
</tr>
<tr>
<td>CASA</td>
<td>Civil Aviation Safety Authority (Australia)</td>
</tr>
<tr>
<td>CASR</td>
<td><em>Civil Aviation Safety Regulations 2001</em> (Cth) (Australia)</td>
</tr>
<tr>
<td>COA</td>
<td>Certificate of Airworthiness</td>
</tr>
<tr>
<td>CS</td>
<td>Certification Specifications (Europe)</td>
</tr>
<tr>
<td>DARPA</td>
<td>Defense Advanced Research Projects Agency (US)</td>
</tr>
<tr>
<td>EASA</td>
<td>European Aviation Safety Authority (Europe)</td>
</tr>
<tr>
<td>ELOS</td>
<td>Equivalent Level of Safety</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration (US)</td>
</tr>
<tr>
<td>FAR</td>
<td>Federal Aviation Regulations (US)</td>
</tr>
<tr>
<td>FMRA</td>
<td><em>FAA Modernization and Reform Act of 2012</em> (US)</td>
</tr>
<tr>
<td>HALE</td>
<td>High Altitude Long Endurance</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation (International)</td>
</tr>
<tr>
<td>JAA</td>
<td>Joint Aviation Authority (Europe)</td>
</tr>
<tr>
<td>MALE</td>
<td>Medium Altitude Long Endurance</td>
</tr>
<tr>
<td>MGTOW</td>
<td>Maximum Gross Take-Off Weight</td>
</tr>
<tr>
<td>MTOM</td>
<td>Maximum Take-Off Mass</td>
</tr>
<tr>
<td>MTOW</td>
<td>Maximum Take-Off Weight</td>
</tr>
<tr>
<td>NAA</td>
<td>National Aviation Authorities</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration (US)</td>
</tr>
<tr>
<td>NPRM</td>
<td>Notice of Proposed Rulemaking</td>
</tr>
<tr>
<td>OBPR</td>
<td>Office of Best Practice Regulation (Australia)</td>
</tr>
<tr>
<td>OECD</td>
<td>Office of Economic Co-Operation and Development (International)</td>
</tr>
<tr>
<td>Term</td>
<td>Meaning</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>RIS</td>
<td>Regulatory Impact Statement</td>
</tr>
<tr>
<td>ROA</td>
<td>Remotely Operated Aircraft</td>
</tr>
<tr>
<td>RPA</td>
<td>Remotely Piloted Aircraft</td>
</tr>
<tr>
<td>RPAS</td>
<td>Remotely Piloted Aircraft System</td>
</tr>
<tr>
<td>RPV</td>
<td>Remotely Piloted Vehicle</td>
</tr>
<tr>
<td>RTCA</td>
<td>Radio Technical Commission for Aeronautics (US)</td>
</tr>
<tr>
<td>sUAS ARC</td>
<td>Small UAS Aviation Rulemaking Committee (US)</td>
</tr>
<tr>
<td>TC</td>
<td>Transport Canada (Canada)</td>
</tr>
<tr>
<td>UAS</td>
<td>Unmanned Aircraft System / Uninhabited Aircraft System</td>
</tr>
<tr>
<td>UAS-AC</td>
<td>Unmanned (Uninhabited) Aircraft System – Air Component</td>
</tr>
<tr>
<td>UASSG</td>
<td>Unmanned Aircraft System Study Group (International)</td>
</tr>
<tr>
<td>UAV</td>
<td>Unmanned Aerial Vehicle / Uninhabited Aerial Vehicle</td>
</tr>
<tr>
<td>UCAV</td>
<td>Unmanned (Uninhabited) Combat Aerial Vehicle</td>
</tr>
<tr>
<td>USAF</td>
<td>United States Air Force (US)</td>
</tr>
<tr>
<td>UVS International</td>
<td>Unmanned Vehicle Systems International (International)</td>
</tr>
</tbody>
</table>
CLASSIFYING UNMANNED AIRCRAFT SYSTEMS

BIBLIOGRAPHY

A Articles / Books / Reports


Baldwin, Robert, Martin Cave and Martin Lodge, Understanding Regulation (Oxford University Press, 2nd ed, 1999)


De Meo, Jr, Lawrence, ‘UAV Operators Are Not Pilots’ (2006) 164(20) Aviation Week & Space Technology 6


Drew, John G, Russell Shaver, Kristin F Lynch, Mahyar A Amouzegar and Don Snyder, Unmanned Aerial Vehicle End-to-End Support Considerations (RAND, 2005)

Farrar, John, Legal Reasoning (Lawbook, 2010)


Fuller, Lon L, ‘Eight Ways to Make Law Fail’ in Lon L Fuller The Morality of Law (Yale University Press, 1964) 33


Gordon, A D, *Classification* (Chapman & Hall/CRC, 2nd ed, 1999)


Kaiser, Stefan A, ‘UAVs and Their Integration into Non-Segregated Airspace’ (2011) 36(2) Air and Space Law 161


Stinchcombe, Arthur, When Formality Works: Authority and Abstraction in Law and Organizations (University of Chicago Press, 2001)


Tremblay, Luc B, The Rule of Law (McGill-Queen’s University Press, 1997)


Twining, William and David Miers, How to Do Things With Rules (Cambridge University Press, 5th ed, 2010)


Vacek, Josef J, ‘Civilizing the Aeronautical Wild West’ (2011) 23(3) Air & Space Lawyer 1

Waller, Louis, David Derham and Francis Maher, Derham, Maher and Waller, an Introduction to Law (LBC Information Services, 8th ed, 2000)


B Cases

Truax v Corrigan, 257 US 312, (Ariz, 1921)

C Legislation, Regulatory Proposals and Related Materials

1 General Australian Legislation

Acts Interpretation Act 1901 (Cth)

Legislative Instruments Act 2003 (Cth)

2 Australian Aviation Legislation and Regulatory Materials

Air Navigation Act 1920 (Cth)

Civil Aviation Act 1988 (Cth)

Civil Aviation Regulations 1988 (Cth)
Civil Aviation Safety Regulations 1998 (Cth)


Civil Aviation Safety Authority, ‘Unmanned Aircraft and Rockets’ (Advisory Circular, No AC 101-1(0), Civil Aviation Safety Authority, July 2002)

Civil Aviation Safety Authority, Unmanned Aircraft and Rockets: Civil Aviation Safety Regulation Part 101, Regulation Impact Statement RIS 0016, 14 March 2001

Explanatory Statement, Civil Aviation Amendment Regulations 2001 (No. 4) 2001 No. 34 (Cth)

3 Canadian Aviation Legislation and Regulatory Materials

Canadian Aviation Regulations, SOR/96-433


4 European Aviation Legislation and Regulatory Materials


5 United Kingdom Aviation Legislation and Regulatory Materials

Air Navigation Order 2009 (UK) SI 2009/3015


Haddon, D R and C J Whittaker, ‘UK-CAA Policy for Light UAV Systems’ (Policy Paper, United Kingdom-Civil Aviation Authority, 28 May 2004)

6 United States Aviation Legislation and Regulatory Materials


FAA Modernization and Reform Act of 2012, Pub L No 112-95
7 International Regulatory Materials


International Civil Aviation Organization, ‘Unmanned Aircraft Systems (UAS)’ (Circular, 328/ AN190, 2011)


D Treaties

*Convention on International Civil Aviation* signed 7 December 1944, 15 UNTS 296 (entered into force 4 April 1947)

E Other


American Institute of Aeronautics and Astronautics (AIAA), History and Heritage (2015) <https://www.aiaa.org/HistoryAndHeritage>


Australian Government, Best Practice Regulation Handbook (Canberra, June 2010)

Australian Government, ‘Defence Instruction (general) ops 02-2’ (Australian Defence Force Airworthiness Management Directive, Department of Defence, Canberra, 2002);


Coyne, James, ‘UAS Regulatory Developments’ (Discussion Paper, Civil Aviation Safety Authority, Undated) <http://www.icao.int/Meetings/UAS/Documents/Coyne-James_CASA_Australia_WP.pdf>


European Aviation Safety Agency (EASA), *Civil Drones* <http://www.easa.europa.eu/easa-and-you/key-topics/civil-drones-rpas>

Fearnley, Paul, ‘Golden Greats’ *F1 Racing* (Middlesex), September 2013, 48


Fraser, C S R and D Donnithorne-Tait, ‘An Approach to the Classification of Unmanned Aircraft’ (Paper presented at 26th International Conference on Unmanned Air Vehicle Systems, Bristol, United Kingdom, 11-12 April 2011)


Hanlon, Mike, *Yamaha's RMAX - the worlds most advanced non-military UAV* (4 June 2014) <http://www.gizmag.com/go/2440>


<http://defensetech.org/2005/07/26/unmanned-is-better/>


Marsh, Rene, *Amazon drone patent application imagines delivery that comes to you with one click* (12 May 2015) CNN Politics


Palmer, J and R Clothier ‘Analysis of the Applicability of Existing Airworthiness Classification Schemes to the Unmanned Aircraft Fleet’ (Paper presented at 15th International Aerospace Congress, Melbourne, 2013)


Senate Standing Committee on Regulations and Ordinances, ‘Role of the Committee’ Parliament of Australia


Sullivan, Jeffrey M, ‘Revolution or Evolution? The rise of the UAVs’ (Paper presented at the International Symposium on Technology and Society, Weapons and Wires: Prevention and Safety in a Time of Fear, Loyola Marymount University, 8-10 June 2005)


‘The last manned fighter’, *The Economist* (London) 14 July 2011, 67


Table 1: UAS Market Data for 2005 - 2015 .......................................................... 26
Table 2: Descriptors for UAS used by UVS International .................................. 29
Table 3: Classification Scheme Used by UVS International .................................. 33
Table 4: CASR Part 101 Classification Scheme .................................................... 86
Table 5: Transport Canada Classification Scheme .................................................. 87
Table 6: CAP722 Classification Scheme .............................................................. 88
Table 7: FAA NPRM Classification Scheme .......................................................... 89
Table 8: sUAS ARC Classification Scheme .......................................................... 90
Table 9: AIAA Classification Scheme .................................................................... 91
Table 10: ASTM International Classification Scheme ............................................ 92
Table 11: EASA A-NPA Proposal 1 Kinetic Energy Tables (Unpremeditated Descent) ... 94
Table 12: EASA A-NPA Proposal 1 Kinetic Energy Tables (Loss of Control) ............ 94
Table 13: EASA A-NPA Proposal 2 Risk Metric Classification ............................... 95
Table 14: EASA ConOps Proposal Classification Scheme ...................................... 96
Table 15: Eurocontrol/IABG Report Classification Scheme ................................... 97
Table 16: Clothier et al Kinetic Energy Classification Scheme ............................... 99
Table 17: Clothier et al Revised Kinetic Energy Classification Scheme .................... 99
Table 18: Clothier et al Risk Matrix Classification Scheme ................................... 101
Table 19: Dalamagkidis et al Initial Classification Scheme .................................... 102
Table 20: Dalamagkidis et al Revised Classification Scheme .................................. 104
Table 21: Fraser and Donnithorne-Tait Classification Scheme ............................... 105
Table 22: Weibel and Hansman Classification Scheme .......................................... 108
Table 23: Kaiser Terminology Scheme .......................................................... 109
Table 24: Peterson Classification Scheme ...................................................... 110
Table 25: Comparison of Criteria used in Current Approaches reviewed in Chapter IV 130
Table 26: Comparison of Class Boundary Selection Methods in Current Approaches .... 133
Table 27: Comparison of Class Designations in Current Approaches ...................... 136
Table 28: Compilation of Stated Desiderata Collected from Literature .................. 140
Table 29: Breakout Showing Application of Rule of Law Principles to Key Decisions .. 183
Table 30: Tabular Representation of CASR Part 101 Classification Scheme ............... 190
Table 31: Illustration of Basic Framework of Reference Constructed from Statutory
Objectives, Rule of Law and Technical Opinions drawn from UAS Literature .......... 205
FIGURES

Figure 1: UAS Weight Class Boundary Comparison based on Current Approaches.......132

Figure 2: Summary of OECD Principles as set out in Argy and Johnson (see n 1003)....175

Figure 3: Overlay of Key Decisions on CASR Part 101 Classification (Refer to Walker, ‘Airworthiness Standards’ above n 503, 1).................................................................192