A FRAMEWORK AND CRITERIA FOR THE OPERABILITY OF UNMANNED AIRCRAFT SYSTEMS

by

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Dissertation presented in fulfilment of the requirements
for the degree of Doctor of Philosophy in Engineering
at Stellenbosch University

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December 2010

DECLARATION

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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ABSTRACT

Airworthiness certification of unmanned aircraft systems (UAS) is normally considered to be a regulatory function. In the absence of comprehensive UAS airworthiness regulations, the development of new and unique UAS, and their introduction into non-segregated airspace, remain major challenges for the UAS industry and regulators. Thus, in response, the objective of this research was to establish a framework and guidelines, within the scope of the typical regulatory regime, that can be used by the UAS engineering domain to ensure the safe and reliable functioning of a UAS, whether regulated or not.

UAS airworthiness is currently mainly based on manned aircraft regulations, and the focus is on the unmanned aircraft and the 'airworthiness' of the remote control station. The typical UAS as a system, however, consists of more than just these elements and a broader approach to the 'airworthiness' of a UAS is required. This study investigated and introduces the concept of UAS operability, where the term 'operability' addresses the safe and reliable functioning of the UAS as a system, the airworthiness of its airborne sub-systems, and the safe and reliable functioning of its non-airborne sub-systems and functional payloads.

To ensure that the results of this study are aligned with typical aviation regulatory systems, a regulatory basis was defined within which UAS operability guidelines could be developed.

Based on the operability concept, and in the scope of the regulatory basis, a UAS operability framework was developed for the UAS engineering domain. This framework is an index and reference source from which appropriate operability elements can be selected for a particular UAS. The scope of the framework is generic, rather than UAS-type or -class specific, and includes operability elements for the UAS as a system, for its airborne and non-airborne sub-systems, and for its payloads.

The framework was validated by developing lower hierarchical levels for the framework and by populating each operability element of the framework with appropriate engineering guidance criteria. The guidance criteria were derived and/or

developed from industry 'best practices' found in the literature, or were newly developed where no existing practices were found.

The significance of this study is found in its establishing of a generic UAS operability framework that not only focuses on the airworthiness of the unmanned aircraft, but addresses the operability of the UAS as a system, as well as the operability of its airborne sub-systems, its non-airborne sub-systems and its payloads.

In practice, the UAS operability framework can be used in the UAS engineering domain as an index and reference source to select relevant operability elements for a particular UAS. The guidance criteria for the selected elements can subsequently be used to develop the appropriate processes, procedures, requirements and specifications to achieve initial operability of the UAS, and to maintain its continued operability.

Although the objective of the research was achieved, the UAS operability framework must still be applied and tested in real-life UAS projects and, where necessary, revised to eliminate shortcomings and to provide for new and novel developments in UAS engineering technologies.

OPSOMMING

Die lugwaardigheidsertifisering van onbemande vliegtuigstelsels (OVS) word normaalweg beskou as 'n reguleringsfunksie. In die afwesigheid van omvattende OVS lugwaardigheidsregulasies bly die ontwikkeling van nuwe en unieke OVS, en die inbedryfstelling daarvan in onafgesonderde lugruim, besonderse uitdagings vir beide die OVS nywerheid en reguleerders. Die doelwit van hierdie navorsing was dus om riglyne binne die bestek van die tipiese reguleringsregime te vestig wat deur die OVS ingenieursdomein benut kan word om die veilige en betroubare funksionering van 'n OVS te verseker, of dit gereguleer word aldan nie.

OVS lugwaardigheid word tans hoofsaaklik gebaseer op lugwaardigheidsvereistes vir bemande vliegtuie. Die fokus is dan ook meerendeels op die onbemande vliegtuig en die 'lugwaardigheid' van die afstandbeheerstasie. Die tipiese OVS bestaan egter uit meer sub-stelsels en 'n weier beskouing van die 'lugwaardigheid' van 'n OVS is nodig. Die konsep van OVS bedryfbaarheid is in hierdie studie ondersoek en voorgestel. 'Bedryfbaarheid' beteken in hierdie konteks die veilige en betroubare funksionering van die OVS as 'n stelsel, die lugwaardigheid van die lug sub-stelsels, die veilige en betroubare funksionering van die nie-lug sub-stelsels, asook die veilige en betroubare funksionering van funksionele loonvragte.

Om te verseker dat die resultate van hierdie studie versoenbaar is met tipiese lugvaart reguleringstelsels, is 'n reguleringsbasis omskryf vir die ontwikkeling van OVS bedryfbaarheidsriglyne.

Gebaseer op die bedryfbaarheidskonsep, en binne die riglyne van die reguleringsbasis, is 'n OVS bedryfbaarheidsraamwerk ontwikkel vir die OVS ingenieursdomein. Die raamwerk is 'n indeks en verwysingsbron waaruit gepaste bedryfbaarheids-elemente gekies kan word vir 'n bepaalde OVS. Die bestek van die raamwerk is generies en nie beperk tot spesifieke OVS tipes of klasse nie. Die raamwerk sluit bedryfbaarheids-elemente in vir die OVS as stelsel, asook vir die lug en nie-lug sub-stelsels van die OVS, en vir die loonvragte van die OVS.

Die raamwerk se geldigheid was bevestig deur die struktuur van die raamwerk tot laer vlakke uit te brei en gepaste ingenieursriglyne vir elke bedryfbaarheids-element in die raamwerk te ontwikkel. Die riglyne was gebaseer op 'beste praktyke' soos beskryf in die literatuur, of was van nuuts af ontwikkel waar geen bestaande praktyke gevind kon word nie.

Die bydrae van hierdie studie is gesetel in die vestiging van 'n generiese OVS bedryfbaarheidsraamwerk wat nie net gemik is op die lugwaardigheid van die onbemande vliegtuig nie, maar wat die bedryfbaarheid in geheel van die OVS as stelsel aanspreek, asook die bedryfbaarheid van die OVS se lug sub-stelsels, nie-lug sub-stelsels en loonvragte.

In die praktyk kan die raamwerk in die OVS ingenieursdomein gebruik word om gepaste bedryfbaarheids-elemente vir 'n OVS te kies. Daarna kan die bedryfbaarheidsriglyne gebruik word om gepaste prosesse, prosedures, vereistes en spesifikasies te ontwikkel om die OVS se aanvanklike en voortgesette bedryfbaarheid te bewerkstellig.

Alhoewel die doelwit vir die navorsing bereik is, moet die OVS bedryfbaarheidsraamwerk nog op werklike OVS projekte getoets word. Waar nodig, moet die raamwerk dan hersien word om tekortkominge, asook nuwe en unieke ontwikkelinge in OVS ingenieurstegnologie, aan te spreek.

ACKNOWLEDGEMENTS

I wish to thank the following persons for their assistance with completing this thesis:

- Prof. Thomas Jones, who accepted me as a Ph.D student and who provided guidance throughout my studies.
- Prof. Theo von Backström, who provided guidance throughout my studies.
- Mr Kim Gorringe, who provided regulatory guidance during the first phase of my studies.
- Col Willie Marais, who supported my studies with encouragement and military advice, and who reviewed drafts, presentations and many ideas.
- Dr Lester Ingham, who provided guidance throughout my studies and who gave up much of his time to review papers and presentations.
- The SA Air Force, for supporting and encouraging my research.
- The South African UAS Co-ordination Committee, for including me in the Committee and Airworthiness Sub-committee and for allowing me to share my research and advice.
- My wife Daleen and my children Leria and Anjo, for their loving support and patience throughout my studies, and without whom I would not have been able to complete this ambitious project.

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ABBREVIATIONS AND ACRONYMS

ADF	Australian Defence Force
ADSM	(Canadian Defense) Airworthiness Design Standards Manual
AIAA	American Institute of Aeronautics and Astronautics
ALARP	"As low as reasonably practicable"
ANNEX 8	Annex 8, Airworthiness of Aircraft, of the Chicago Convention
AST	Office of the Associate Administrator for Commercial Space Transportation, United States of America Federal Aviation Administration
ASTM	American Society for Testing and Materials
CAA	Civil Aviation Authority
CARCOM	(South African) Civil Aviation Regulations Committee
CASA	Australian Civil Aviation Safety Authority
CASR	Australian Civil Aviation Safety Regulations
CF	Canadian Forces
CS	(European Aviation Safety Agency) Certification Specifications
DGA	(French) Délégation Générale des Armements
DND	(Canadian) Department of National Defense
EASA	European Aviation Safety Agency
EC	European Community
EMAAG	European Military Aviation Authorities Group
EUROCAE	European Organisation for Civil Aviation Equipment
EU	European Union
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAA	(United States of America) Federal Aviation Administration
FAR	(United States of America) Federal Aviation Regulations
FLYGI	Swedish Military Flight Safety Inspectorate
ICAO	International Civil Aviation Organisation

IEEE	Institute of Electrical and Electronic Engineers
IMAAC	International Military Aviation Authorities Conference
"IMAO"	"International Military Aviation Organisation"
JAA	Joint Aviation Authorities
JAR	European Joint Airworthiness Requirements
kg	kilogrammes
NAEW&CFC	NATO Airborne Early Warning and Control Force Command
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organisation
RLV	Reusable Launch Vehicle
RLVs	Reusable Launch Vehicles
RML	Swedish Rules of Military Aviation
RTCA	Radio Technical Commission for Aeronautics
RTI	(United States of America) Research Triangle Institute
SA	South Africa
SA CAA	South African Civil Aviation Authority
SA-CAR	South African Civil Aviation Regulations
TAM	(Canadian Defense) Technical Airworthiness Manual
UAS	Unmanned Aircraft System/s
UASSG	(ICAO) UAS Study Group
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
UK CAA	United Kingdom Civil Aviation Authority
USA	United States of America
USAR	(French DGA) UAV Systems Airworthiness Requirements

1. INTRODUCTION

1.1. Introduction

This thesis focuses on establishing a guidance framework for achieving and maintaining operability of unmanned aircraft systems (UAS), their airborne sub-systems, their non-airborne sub-systems and their payloads.

The objective of the research that culminated in this thesis originally targeted the development of continuous airworthiness criteria for UAS for both the engineering and regulating domains. However, the research process was frustrated by the lack of consolidated and generic UAS-unique initial airworthiness requirements, since such requirements usually form the basis for the development of continuous airworthiness criteria. Thus, upon evaluation of the results of the initial work carried out for this research, it was decided to adapt the focus of the research to investigate the need for ensuring the safe and reliable engineering functioning of the UAS as a system, rather than just the airworthiness of the aircraft, and to define an appropriate operability framework that will ensure that safe and reliable functioning. Populating it with relevant operability criteria that can be utilised to develop specific UAS operability requirements proved the validity of the operability framework. Finally, it was decided to limit the research to the engineering domain only, rather than conduct it for both the engineering and regulating domains. The primary steps of the research process are shown in Figure 1.1.

Although there are similarities, UAS are significantly different to other systems that operate in navigable air and space. Where UAS are to be allowed unlimited access to airspace, airworthiness-related issues need to be addressed by means of safety regulation[1,2,3,4]. From an engineering perspective, it is equally important to ensure that UAS can carry out their functions as and when required, whether the UAS are regulated for safety or not. Neither airworthiness requirements for manned aircraft, nor flightworthiness criteria for spacecraft adequately address the unique airworthiness-related characteristics of UAS.

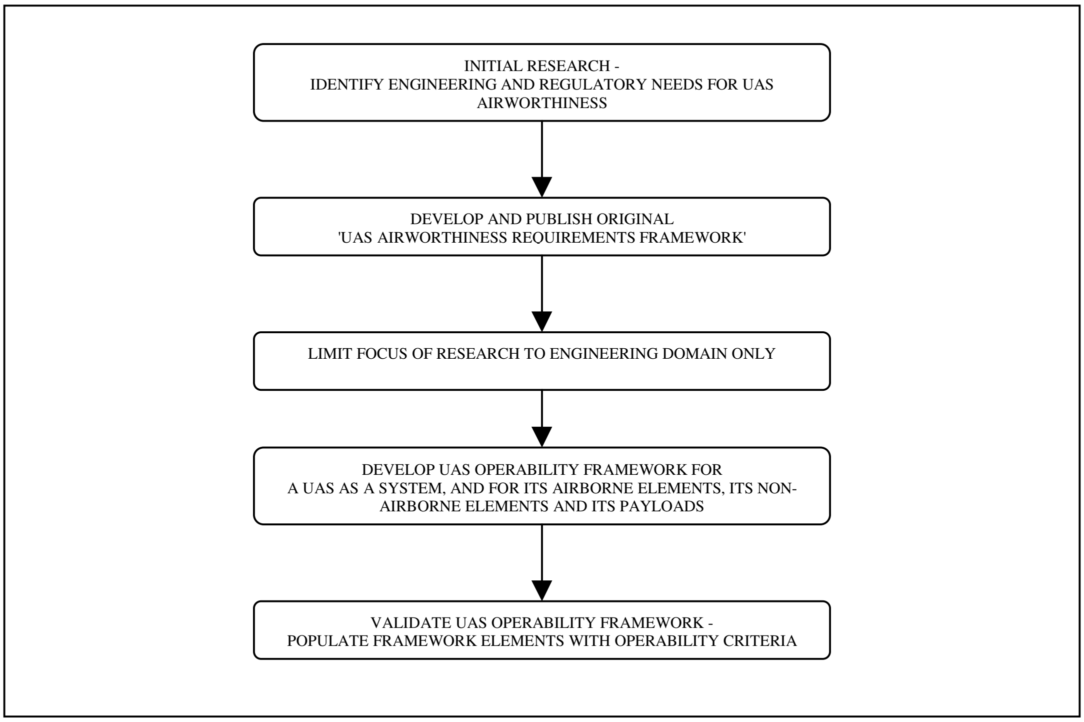

Figure 1.1 Primary steps followed during the research process.

A new approach is therefore required and this study:

- introduces the concept of UAS operability to describe the safety and reliability status of a UAS;
- reviews the regulatory domain within which UAS operability criteria can be developed for utilisation in the engineering domain; and
- develops and presents a generic 'UAS Operability Framework' with criteria from which initial and continued operability requirements for UAS, their airborne sub-systems, their non-airborne sub-systems and their payloads can be developed.

The study resides in the engineering domain and specifically addresses engineering criteria associated with the safe and reliable functioning of UAS, within the established scope of aerospace regulatory frameworks.

From a traditional aviation perspective, an aircraft is considered to be a system on its own and the airworthiness, rather than the operability, of the aircraft is regulated to ensure the safe and reliable functioning of the aircraft. A UAS as a system, however, usually consists of several sub-systems that are both airborne and non-airborne. Since airworthiness specifically focuses on the airborne ability of an aircraft, limiting this study to a discussion of airworthiness requirements only would theoretically need to exclude the non-airborne sub-systems.

This study therefore introduces the concept of 'UAS operability', where the operability of a UAS is defined to include:

- the reliable and safe functioning of the UAS as a system;
- the airworthiness (reliable and safe functioning) of the airborne sub-systems of the UAS, including the aircraft and any other airborne sub-systems required for the functioning of the UAS;
- the reliable and safe functioning of the non-airborne sub-systems of the UAS; and
- the reliable and safe functioning of payloads to be carried in or on the UAS aircraft.

The term 'airworthiness' will be used to address those aspects that are included in the traditional meaning of the term.

1.2. Hypothesis

Although airworthiness criteria, rather than operability criteria, for a UAS and its sub-systems can be derived and tailored from examples of manned aircraft system manuals and airworthiness regulations, such an approach would limit the scope of the criteria and my hypothesis is that:

- a generic 'UAS Operability Framework' can be established, within the scope of typical aerospace regulatory frameworks, to address the initial and continued operability of UAS, their airborne sub-systems, their non-airborne sub-systems and their payloads; and
- the 'UAS Operability Framework' can be validated by populating it with appropriate criteria from which engineering requirements can be developed for the initial and continued operability of a UAS, including the system, its airborne sub-systems, its non-airborne sub-systems and its payloads.

1.3. Background

The development of legislation for integrating civil and military UAS safely into national airspace is in progress in numerous countries with the United Kingdom, Europe, the United States of America, and Australia leading the primary efforts in this regard[5,6,7,8,9]. In South Africa, similar efforts have resulted in a roadmap for the introduction of UAS into South African airspace[5], and the development of a functional reference framework of airworthiness requirements for UAS[9]. An interim policy and procedure document for regulating the airworthiness and operation of civil UAS in South Africa was approved by the South African Civil Aviation Regulations Committee (CARCOM) in 2008[10] and similar policies and procedures are expected to also become applicable to military UAS in South Africa[11].

At international level, the International Civil Aviation Organisation (ICAO) established a specialised UAS Study Group (UASSG)[12,13,14] to initiate the development of international regulations for civil UAS. Since a military equivalent of ICAO does not exist[15], the developing of rules/regulations and requirements for military UAS is primarily carried out by national armed forces, by national military aviation regulating authorities, or by organisations such as the North Atlantic Treaty Organisation (NATO)[16,17].

With specific reference to UAS operability, an initial survey of existing aviation and aerospace airworthiness requirements[9] revealed that:

- a generic and comprehensive set of UAS-unique airworthiness and continued airworthiness regulations and requirements does not yet exist[18];
- the term 'operability' is not used for UAS as systems, and system and sub-system level operability and continued operability criteria have therefore not been developed for UAS[18];
- airworthiness requirements for manned aircraft do not address all the sub-systems of a UAS. Typically, requirements for non-airborne sub-systems and functional payloads of a UAS are not included[2,18];
- a limited number of industry standards for selected aspects of UAS have been developed or are being developed; and

- many similarities exist between UAS and reusable launch vehicles (RLVs), where knowledge and requirements published for RLVs could be useful guidance in the development of parallel criteria for UAS.

The survey also indicated that the direct application of manned aircraft airworthiness requirements to UAS is not always feasible[18]. The tailoring of selected manned aircraft requirements is currently applied as an interim arrangement[5,9,10,18], as it is expected that the global efforts toward developing UAS-unique airworthiness and operating regulations will not be completed soon[9,18]. It is also anticipated that some UAS types may be excluded from formal regulatory regimes, in which case the UAS developer will be responsible for assuring the engineering safety and reliability of such UAS[10,19].

It is both an objective and a requirement to integrate UAS safely and reliably into non-segregated airspace[5]. Against the background of these ideals, however, the UAS industry awaits pro-active regulatory guidance with regard to UAS airworthiness requirements, while the regulating authorities would prefer to develop such regulatory guidance reactively in response to specific UAS developments[5]. Although some regulations have been implemented, regulatory systems for UAS in most cases still lag engineering progress, resulting in a continual restraining of the development process of existing and new UAS, and in particular of those UAS that utilise emerging new technologies.

1.4. Problem Statement and Objectives of Study

From the above considerations, the problem statement for this study is defined as follows:

- Comprehensive and generic UAS airworthiness/operability regulations have not yet been implemented globally[5,6,9], causing the delay of unconditional introduction and integration of UAS into regulated and controlled airspace, particularly for civil and commercial applications;
- generic UAS operability and continued operability criteria for utilisation in the engineering domain have not been developed;
- the lack of regulating guidelines for the airworthiness/operability of UAS is

resulting in the development of UAS that are based primarily on client specifications and functionality requirements, with lesser regard for following consistent and generally accepted engineering processes and regulating requirements; and

- the concept of operability of a UAS as a system, as well as the operability of all its sub-systems and payloads, is not addressed in existing UAS or manned aircraft regulations[5,9,18,19].

The primary objective of this study is to develop an operability framework and criteria for UAS, whether regulated or not and whether regulations exist or not, that will enable the UAS engineering domain to:

- ensure consistency in the engineering processes that are applied in the design, development, manufacture and maintenance of UAS;
- ensure that necessary and relevant processes, procedures, criteria and requirements are developed and applied in the development of the UAS to ensure that the safe and reliable functioning of the UAS, its sub-systems and its payloads is achieved and maintained; and
- demonstrate to regulating authorities, if and when required to do so, that the engineering processes and the UAS conform to a scientifically developed set of UAS operability criteria.

A secondary objective of this study is to ensure that the UAS operability framework and criteria, although developed for the engineering domain, will be compatible with the majority of UAS regulating requirements when these requirements are eventually implemented.

To achieve these objectives, this study should investigate the stated problems and should:

- introduce and define the concept of UAS operability;
- review the regulatory domain within which the UAS operability framework and criteria can be developed for utilisation in the engineering domain;
- investigate the feasibility of developing a generic UAS operability framework, within the scope of typical aerospace regulatory frameworks, to address the

operability criteria and requirements for UAS, their airborne sub-systems, their non-airborne sub-systems and their payloads; and

- validate the operability framework by populating it with appropriate, generic UAS operability criteria from which the engineering domain can develop relevant engineering requirements for the initial and continued operability of a specific UAS, its airborne sub-systems, its non-airborne sub-systems and its payloads.

1.5. Research Questions

Beyond the scope of the traditional airworthiness requirements prescribed in aviation regulations, an entity such as an unmanned aircraft system, with emphasis on the ***system***, should be evaluated against a broader scope of requirements. The safe and reliable functioning, or operability, of a UAS as a system should be ensured, as well as the airworthiness of the airborne sub-systems of the system, and the safe and reliable functioning of its non-airborne sub-systems and functional payloads. In addition, although the initial operability of the UAS is essential for obvious reasons, the operability criteria should also ensure that continued operability is maintained for the UAS, its sub-systems and its payloads.

This study therefore focuses on establishing an appropriate operability framework for UAS and to achieve the objectives of the study, the research questions that must be addressed are:

- Is the concept of UAS operability feasible and can it be defined?
- Can a regulatory domain be identified within which a UAS operability framework and criteria can be developed for utilisation in the engineering domain?
- Can a generic UAS operability framework, within the scope of typical aerospace regulatory frameworks, be developed to address the operability criteria and requirements for UAS, their airborne sub-systems, their non-airborne sub-systems and their payloads?

and

- Can the operability framework be validated by populating it with appropriate, generic UAS operability criteria from which the engineering domain can develop relevant engineering requirements for the operability of a specific UAS, its airborne sub-systems, its non-airborne sub-systems and its payloads?

1.6. Scope and Context of Study

The scope of this study is limited to the establishing of a generic UAS operability framework, and the validation of the framework by populating it with relevant UAS operability criteria from which engineering requirements for a UAS can be developed. The framework and its populating criteria are developed from an engineering perspective, rather than regulatory, and are not limited to a specific category or type of UAS. Although the presently envisaged spectrum of UAS operability issues is addressed in detail, the derivation of specification-level engineering requirements from the operability criteria is considered to be beyond the scope of this study.

To ensure appropriate acceptance by both civil and military aviation authorities of UAS that are developed in terms of the operability framework and criteria presented in this thesis, the study and the development of the framework and criteria were done within the context of typical aviation and space regulatory frameworks. The structure and ordering of the UAS operability framework is based on the standard structures of airworthiness and flightworthiness regulations, appropriately tailored and expanded to be generic, and augmented to include non-airborne sub-systems and payloads.

1.7. Significance and Contribution of Study

Although various airworthiness-related regulations and standards have been published for specific categories of UAS, a generic approach for the UAS engineering domain as presented in this study, has not previously been established.

The significance of this study is therefore found in its establishing of the generic UAS operability framework that addresses not only the airworthiness of UAS aircraft, but the total operability of UAS as systems, as well as the operability of their airborne sub-systems, their non-airborne sub-systems and their payloads. The generic character of the framework was achieved by:

- evaluating existing engineering and regulatory guidelines from the unmanned and manned aviation domains;
- evaluating the previously-ignored engineering and regulatory guidelines from the re-useable space launch vehicle (RLV) domain; and

- creating a consolidated framework structure that addresses all aspects identified, and introduced, to be associated with UAS operability.

The significance of the study is further enhanced with the reference engineering criteria with which the UAS operability framework is validated, and which were developed for use in the UAS engineering domain as reference criteria for specific and tailored operability and continued operability requirements for a particular UAS.

The potential contributions of the study are found in the following:

- Rather than using the limited scopes of the terms 'airworthiness' or 'flightworthiness', the concept of 'UAS operability' was introduced and defined to generically address the safe and reliable functioning status of a UAS as a system, as well as of its sub-systems.
- By establishing the UAS operability framework and validating it with operability criteria, a single instrument was created that contains all airworthiness- and operability-significant issues of a UAS and its sub-systems.
- As an engineering 'checklist', the UAS operability framework is a comprehensive and generic index of operability criteria that can be tailored and applied to a specific UAS development project to ensure that all relevant operability issues are addressed.
- As an engineering reference work, applicable operability criteria can be selected from the populated UAS operability framework and developed into engineering requirements for a specific UAS development project to ensure that the appropriate engineering effort is carried out to achieve initial operability of the UAS, and to maintain its continued operability.
- As a general reference framework, the UAS operability framework, and its criteria, can be utilised by regulating authorities as a guideline for tailoring and/or developing airworthiness and operability regulations and requirements for UAS in general, or for specific UAS on a case-by-case basis.

1.8. Outline of Thesis

This thesis is divided into eight chapters. Chapter 1 introduces the research subject and gives an overview of the study, including its background, its purpose and its research questions. Chapter 2 addresses the first research question and defines the concept of UAS operability. In Chapter 3, the second research question is addressed with a review of the regulatory environment for UAS and the definition of a regulatory domain for UAS operability. Chapter 4 describes the approach used to conduct the research, including the research tools, data analysis and framework development methods, evaluation methods and limitations of the study. Chapter 5 addresses the third research question with a description of the development of the UAS operability framework. Chapter 6 provides a description of the validation process of the operability framework and addresses the final research question. Chapter 7 describes the contribution of this study in respect of the research questions, as well as the general contributions of the study to the UAS body of engineering knowledge. The study is concluded with Chapter 8 in which the research results are summarised and recommendations for further research and development work are given. The appendices to this study include results of the initial work carried out in respect of this study, as well as the UAS operability framework, both in its structural format, and as populated with operability criteria.

2. UAS OPERABILITY

2.1. Introduction

The first research question of this study is concerned with whether the concept of UAS operability is feasible and whether it can be defined. This concept is investigated in this chapter.

As mentioned in the introduction to this thesis, an aircraft is traditionally considered to be a system on its own and its airworthiness is regulated to ensure the safe and reliable functioning of the aircraft. Similarly, the 'flightworthiness' of spacecraft is regulated to ensure the safe operation of the spacecraft[20,21].

An unmanned aircraft ***system***, however, consists of various sub-systems that are both airborne and non-airborne[2]. Therefore, when the 'airworthiness', or safe and reliable functioning, of the UAS is to be achieved, it is necessary to consider the following:

- the safe and reliable functioning of the UAS as a system;
- the airworthiness of all the airborne sub-systems of the UAS;
- the safe and reliable functioning of all the non-airborne sub-systems of the UAS; and
- the safe and reliable functioning of relevant payloads to be carried by the UAS.

To only consider typical airworthiness requirements will not ensure that the UAS as a system, the non-airborne sub-systems and the payloads will function safely and reliably. In addition, the term 'airworthiness' appears to limit its applicability to items that can become airborne, and to group non-airborne items with airborne items will obscure the significance of the safe and reliable functioning of the non-airborne items.

Since this study is not limited to considering the airworthiness of the aircraft sub-system of the UAS only, it is necessary to introduce a term that can effectively describe the safe and reliable functioning status of a UAS, and of all its sub-systems, in such a manner that it can be applied generally in both the engineering and the regulating domains, as well as uniquely to the UAS as a system, and separately to each of the UAS sub-systems.

In this chapter, therefore, the role of 'airworthiness' is described and the concept of UAS operability is introduced.

2.2. Airworthiness

Although airworthiness is central to the regulation of aviation safety at international and national levels, it is noteworthy that the term 'airworthiness' is not defined explicitly in any of the following:

- the Chicago Convention and its Annexes[1];
- the USA Federal Aviation Regulations (FAR)[22];
- the European Joint Airworthiness Requirements (JAR)[23]; and
- EASA's Certification Specifications (CS) [24].

To develop the concept of UAS operability, however, an acceptable definition for 'airworthiness' is necessary to ensure a common understanding of the objective of achieving an acceptable airworthiness state. For the purposes of this study, the following definition from the UK Military Airworthiness Regulations[25] was selected:

> Airworthiness is "the ability of an aircraft or other airborne equipment or system to operate without significant hazard to aircrew, ground crew, passengers (where relevant) or to the general public over which such airborne systems are flown"[25].

Note that emphasis is placed on the aircraft, or, for UAS, the airborne sub-system/s of the system.

In addition:

> Hazard, or risk, reduction is achieved by improving safety and is defined to be as low as reasonably practicable "when it has been demonstrated that the cost of any further risk reduction, where cost includes the loss of capability as well as financial or other resource costs, is grossly disproportionate to the benefit obtained from that risk reduction"[25].

Airworthiness is therefore achieved by applying sound engineering and aeronautical practices to the design, manufacturing and maintenance of an aircraft in order to reduce the safety risks associated with it to as low a level as reasonably practicable (the so-called "ALARP" principle[25]).

Consistency in the airworthiness of regulated aircraft of a particular type, or design, is currently achieved by means of the type or design certification process and the issuing of certificates of airworthiness. In type/design certification, a competent aviation authority validates the design of an aircraft against, and certifies the design to comply with, a set of pre-determined aeronautical safety requirements. Subsequent to manufacturing, the airworthiness of each aircraft is validated against the certified design by inspection, and confirmed with the issuing of a renewable certificate of airworthiness. Ongoing compliance with the safety requirements is required and overseen by the authority, and is accomplished by the aircraft owner or operator through a continued airworthiness programme of inspections and maintenance for each aircraft.

In civil aviation, the safety requirements are typically prescribed in aviation regulations and industry standards. In military aviation, acquisition specifications typically prescribe the detailed safety requirements, acceptable aviation regulations (military and/or civil) and acceptable standards (military and/or industrial) that are to be used to achieve airworthiness.

2.3. Introducing the Concept of UAS Operability

The term 'airworthiness' is usually associated with an aircraft, rather than an aircraft system, and the less familiar term 'flightworthiness' is usually associated with spacecraft such as reusable launch vehicles (RLVs)[20,21]. Flightworthiness is defined as an aircraft, missile or spacecraft that "is ready and sufficiently sound in all respects to meet and endure the stresses and strains of flight"[26].

In order to address the safe and reliable functioning status of all UAS sub-systems, as well as of the UAS as a system, and because of the limited scopes of the 'airworthiness' and 'flightworthiness' terms, a more collective approach is required in considering the 'airworthiness' or 'flightworthiness' of the UAS and its sub-systems.

It was found that a generally-used collective term to address all systems and sub-systems of UAS, similar to 'airworthiness' or 'flightworthiness', does not exist in most of the prominent aviation and space transportation regulations[1,20,22,23,24]. Thus, addressing the safe and reliable functioning status of a UAS would require:

- a change in the interpretation and the meaning of the term 'airworthiness';
- the use of a different term already in use, such as the term 'flightworthiness', which is used for RLVs; or
- the introduction of a specific and generic term to address all airworthiness, safety and reliability issues of a UAS.

To avoid confusion in the normal manned aircraft regulatory domains, a change in the interpretation and meaning of the term 'airworthiness' is not recommended.

The use of the term 'flightworthiness' is potentially feasible. However, the term is typically associated with RLVs and it is not defined to include all RLV sub-systems. Its use for UAS could therefore again cause confusion in both the UAS and RLV domains and it is recommended that the term "flightworthiness' not be used for UAS.

Following the above considerations, it was decided to search for, or invent, an appropriate new term. A dictionary search revealed that the terms 'operable' and 'operability' were relevant for the purposes of this study. A selection of printed and online dictionaries define these terms as follows:

- operable - able to be used[27];
- operable - capable of being put into practice (noun - operability)[28];
- operable - able to work[29];
- operable - fit or ready for use or service; "an operational aircraft"; usable for a specific purpose[30];
- operable (domain definition: energy) - "a system, subsystem, train, component, or device is operable or has operability when it is capable of performing its specified functions, and when all necessary attendant instrumentation, controls, electrical

power, cooling or seal water, lubrication or other auxiliary equipment that are required for the system, subsystem, train, component or device to perform its functions are also capable of performing their related support functions"[30];

- operability - "Operability is the ability to keep an equipment, a system or a whole industrial installation in a safe and reliable functioning condition, according to pre-defined operational requirements. In a computing systems environment with multiple systems this includes the ability of products, systems and business processes to work together to accomplish a common task such as finding and returning availability of inventory for flight. In the gas turbine engine business, engine operability is the ability of the engine to operate without compressor stall or surge, combustor flame-out or other power loss. Operability engineers work in the fields of engine and compressor modeling, control and test to ensure the engine meets its ignition, starting, acceleration, deceleration and over-speed requirements under the most extreme operating conditions. Operability is considered one of the ilities and is closely related to reliability, supportability and maintainability."[31].

From these definitions, the term 'operability' was selected to collectively and individually address the safety-related and reliable functioning issues, including airworthiness, of the UAS as a system, as well as of its sub-systems.

For the purposes of this study, therefore, the operability of a UAS is defined to include:

- the safe and reliable functioning of the UAS as a system;
- the airworthiness of all the airborne sub-systems of the UAS;
- the safe and reliable functioning of all the non-airborne sub-systems of the UAS; and
- the safe and reliable functioning of relevant payloads to be carried by the UAS.

It is clear from this definition that UAS operability is not limited to a particular category or type of UAS, but can be applied to all UAS, whether regulated or not, and whether military or civilian.

2.4. Summary

In respect of the first research question of this study, it can be concluded that the concept of 'UAS operability' is not only feasible, but is necessary, if all aspects of a UAS are to be considered to ensure its safe and reliable functioning. Also, to be generic, 'UAS operability' has been defined to be applicable to all UAS.

Although this study focuses on the engineering perspective of UAS operability, the fact that most UAS will be subjected to some level of safety regulation remains a reality and it is therefore necessary to consider the regulatory environment that will apply to UAS. The purpose of the next chapter, then, is to review the regulatory environment for UAS and to identify a regulatory domain within which a UAS operability framework can be developed for utilisation in the engineering domain.

3. REGULATORY DOMAIN FOR UAS OPERABILITY

3.1. Introduction

The previous chapter confirmed that the total operability of UAS should be investigated, rather than just their airworthiness. The process of developing an appropriate UAS operability framework should therefore now commence, provided that it complies with the secondary objective of the research, which requires that the UAS operability framework and criteria should be compatible with UAS regulating requirements.

Reflecting on the scope and purpose of this study, it can be argued that an engineering investigation of UAS operability criteria should not be bound by regulatory constraints, especially since appropriate and comprehensive UAS regulations have not yet been defined. However, compliance with applicable UAS regulations will be required in the future and the earlier the engineering development of a new UAS is aligned with regulating constraints, or at least with the philosophy of the regulating approach, the more successful and cost effective such compliance will be.

The second research question therefore asks:

- Can a regulatory domain be identified within which a UAS operability framework and criteria can be developed for utilisation in the engineering domain?

In order to establish an operability framework with criteria for UAS, it is necessary to consider the regulatory environments in which UAS would typically have to operate. By identifying and applying the regulatory domain for UAS, the operability framework and criteria can be developed to satisfy engineering requirements for safe and reliable UAS functioning, while complying with the scope of the anticipated UAS regulatory domain, when such compliance is required.

This chapter investigates the supporting background to the regulatory domain for UAS operability by means of an overview of general regulatory concepts, and a review of international and national approaches in aviation regulation, including trends in UAS airworthiness regulation. A UAS regulating domain is then proposed on the basis of a plausible legislative basis for UAS regulation, and recommendations regarding the required technical scope and process of application of the regulating domain are made on the basis of the results of a UAS scenario study.

3.2. Regulatory Concepts

3.2.1. Introduction

This section considers popular motives for regulating aviation, summarises the prominent regulatory styles and approaches, summarises how they are applied in aviation, and lists criteria for ensuring effective regulation. This information is used to derive a "checklist" that is applied in the evaluation of selected aviation regulatory systems, legal bases and the scope of their technical content.

3.2.2. Motives for Regulation

For the purposes of this study, regulation is defined as a deliberate application of public policy[32] to control industrial and social behaviour by means of rules[27,33]. Regulation includes the promulgation and enforcement of rules that are based on future-oriented policies[32], or on event-generated knowledge. Although regulation is perceived to be restrictive or preventative in controlling behaviour, it can be applied constructively[33].

Motives for regulation[33] that are most relevant to aviation include the following:

- promotion of key industries;
- promoting public acceptance of new technologies and industries;
- ensuring availability of essential services, such as air traffic control services;
- protection of vulnerable interests, such as public and property safety, and strategic industries;
- the prevention of undesirable behaviour, such as noise and air pollution; and
- protection of future generations through controlled co-ordination and planning.

In addition to motives for regulation, various styles and approaches exist from which to develop an appropriate regulating system.

3.2.3. Regulatory Styles and Approaches

Different regulatory styles and approaches are used to achieve particular regulated outcomes. At state level, approaches are typically based on the state's functional capacities to influence behaviour and on the anticipated results[33]. Primary legislative functions[33] include, amongst others, the capacity to:

- command, using the authority of the law;
- redistribute wealth, by using taxes[34], contracts, loans, and subsidies;
- control markets and market elements;
- inform the market and the public;
- intervene, using the state's own resources; and
- confer statutory rights, by identifying privileges and liabilities.

By matching particular objectives with specific functional capacities, different regulatory styles and approaches have evolved over time. Examples of styles[33] that are generally used in regulation include:

- **Command and Control**. The force of law and fixed standards define minimum acceptable levels of behaviour, is protective of the public, and forcefully applies penalties. This style is cumbersome to administer and enforce, and its rules are difficult to optimise.
- **Self-Regulation**. The market develops and enforces its own rules, resulting in reduced costs to the state and flexibility in the administration of the process. Transparency and public trust in this style are often lacking, and costly state intervention is required when it fails.
- **Market Control**. Market activities are controlled with competition laws, franchising of public services, and sub-contracting of state and local authority services. State oversight is required and the potential for abuse exists.
- **Direct Action**. Where the state has long-term objectives or must protect strategic interests, direct state intervention in the market may be required. Such action may be costly and may disrupt normal market activities.
- **Rights and Liabilities Laws**. Constitutional and statutory rights are conferred on members of the public who have the option to enforce or decline the rights, requiring minimal state intervention.

In practice, including in aviation, a combination of styles is usually applied to derive the desired regulatory strategy[33]. Once a regulating strategy has been selected, the most appropriate regulating approach, or combination of approaches, must be selected. The most common approaches are usually arranged in a "hierarchy of approaches"[35], and include:

- **Prescriptive approach**, in which regulations and compliance requirements are exhaustively detailed with rigid prescriptions. The authority assumes primary responsibility for achieving the objectives, and enforces compliance by means of strict inspection programmes.
- **Performance based approach**. Specific regulatory objectives are prescribed, and regulations and compliance requirements are more flexible with less prescriptive detail. The regulated entity has more responsibility in determining how to achieve the objectives, while the authority must approve and oversee its own compliance details, as well as those developed by the regulated entity.
- **Principle based approach**. Broad regulatory principles, or objectives, are given and no compliance requirements are prescribed, thus allowing for full flexibility in the compliance process. The regulated entity is fully responsible for determining how to achieve the objectives, whereas the responsibilities of the authority include approving and overseeing the compliance processes from the regulated entities.

The prescriptive approach has been the norm in aviation regulation for many decades, but consideration is now being given to migrate towards performance based approaches to achieve more effective regulatory systems[36,37].

3.2.4. 'Good' Regulation

Regulation can be "good, acceptable or in need of reform"[33]. In 2004 the Canadian "External Advisory Committee on Smart Regulation" reported that the existing Canadian regulatory system inhibited innovation, competition and commerce, and serious changes were required to make the system "more effective, responsive, cost-efficient, transparent and accountable"[38]. Although this is an example of a large-scale reform process, the motivation for the reform of other regulatory systems could be equally applicable. Therefore, in developing a regulatory domain for UAS it must be borne in mind that the effectiveness of a regulating system is influenced by a number of basic criteria, including[33,35]:

- correctly defining the primary problem;
- ensuring that government action is justified;
- establishing a legal basis for the required regulation;
- selecting the appropriate regulating styles and approaches;
- ensuring that the benefits derived from regulation justify the cost of regulation;
- developing regulations that are clear and comprehensible;
- confirming that the regulator has the necessary competence;
- ensuring that compliance with the regulations is achievable; and
- ensuring that the regulator is accountable and controlled, and the regulatory system is implemented efficiently.

These criteria, in addition to the other regulatory concepts described in this section, will be used to determine the effectiveness of the regulatory approaches and processes presented in the following sections.

3.3. Legal Basis for UAS Operability Regulation: Civil Aviation

3.3.1. General Regulation of Civil Aviation

In 1919 the Convention for the Regulation of Aerial Navigation (Paris Convention) established a legal foundation for rights in international civil aviation[39]. This Convention determined that "every nation has absolute and exclusive sovereignty over the airspace above its defined territory"[39]. This principle remained the cornerstone for the drafting of the Convention on International Civil Aviation (Chicago Convention)[1] in 1944. Annexes to the Convention focus on national requirements[39], and the International Civil Aviation Organisation (ICAO) was established to give effect to the mandates of the Convention. In terms of the Chicago Convention and its Annexes, ICAO contracting states are mandated to develop national legislation to regulate civil aviation within their national borders. The primary regulated elements of civil aviation include[1,15,18]:

- aircraft airworthiness and continued airworthiness;
- flight operations and operators;

- personnel licensing;
- aviation organisations and facilities; and
- air traffic and other aeronautical services.

For international civil aviation, therefore, the Chicago Convention and its Annexes form the legal basis for its regulation. However, the Convention and its Annexes also mandates national civil aviation legislation (statutory laws), which then forms the basis for the regulation of, amongst others, the airworthiness of all registered civil aircraft in ICAO contracting states.

3.3.2. Regulation of Airworthiness in Civil Aviation

ICAO first adopted airworthiness standards and recommended practices in 1949 in accordance with Article 37 of the Chicago Convention[1] and designated those standards and practices as Annex 8, Airworthiness of Aircraft[40], to the Convention.

In 1956 the standards contained in Annex 8 were supplemented with mandatory "Acceptable Means of Compliance", the majority of which were developed in 1957. In 1972, a review of the ICAO airworthiness policy resulted in the Acceptable Means of Compliance being abandoned in favour of technical guidance material with no mandatory implications or obligations. The review also confirmed that "each Contracting State should either establish its own comprehensive and detailed code of airworthiness or select a comprehensive and detailed code established by another Contracting State"[40].

The policy review subsequently resulted in the present ICAO policy on airworthiness, which provides as follows[40]:

- the objective of Annex 8 is to define the minimum level of airworthiness for international recognition of certificates of airworthiness, issued by ICAO contracting states, to ensure the safety of other aircraft, third parties and property;
- the standards contained in Annex 8 meet the obligations of ICAO under the Chicago Convention to adopt international standards of airworthiness;
- the technical airworthiness standards in Annex 8 are presented as broad objectives, rather than the means of achieving the objectives, and national

airworthiness regulations should contain the necessary level of detail required for the issuing of certificates of airworthiness; and
- to assist ICAO contracting states in applying Annex 8, and in developing their national airworthiness regulations in a uniform manner, detailed guidance material is published by ICAO in the ICAO Airworthiness Manual[41].

For ICAO contracting states, Annex 8 therefore provides a framework for the regulation of airworthiness, although it must be noted that Annex 8 is limited in its scope and only provides for:
- the administration of airworthiness and continued airworthiness;
- fixed wing aircraft with a maximum certified take-off mass of more than 5700 kg that are to be used for transporting passengers and cargo[40]; and
- helicopters that are to be used for passenger and cargo transportation[40].

3.3.3. Current Approaches to Regulating the Airworthiness of Civil UAS

International

At international level, Article 8 of the Chicago Convention applies to "pilotless aircraft"[1] and the standard approach of ICAO contracting states is to regulate civil UAS equivalently to manned aircraft[2,18,42,43,44]. Since important differences do exist between manned and unmanned aircraft[5,9], the ICAO process to establish specific international guidelines for regulating UAS started with a first "Exploratory Meeting" in 2006[12]. This meeting recommended that ICAO should co-ordinate the drafting of a strategy that would address at least the following UAS issues:
- regulations, including common standards to serve as the basis for national regulations;
- initial and continued airworthiness;
- operations;
- personnel training and licensing;
- technical issues, such as frequency spectrums, “sense and avoid”, data link issues, and separation minima;
- certification of related organisations;
- human factors;

- public acceptance;
- environmental issues; and
- security.

At a second meeting held in 2007[13], it was decided that ICAO should develop a regulatory concept and co-ordinate the development of ICAO standards and recommended practices for civil UAS. Reflecting ICAO's current regulatory approach, the meeting agreed that the standards and recommended practices should be performance-based.

It was also determined that the Annexes of the Chicago Convention would eventually need revision to provide for UAS[13]. This implies that the Chicago Convention will remain the legal basis for the general regulation of international civil aviation, both for manned and unmanned aircraft. It therefore also follows that Annex 8[40] of the Convention will remain the international legal basis for the regulation of the airworthiness of civil UAS.

National

National approaches towards regulating civil UAS and their airworthiness are usually based on existing regulations for manned aircraft, or regulations for radio controlled model aircraft for certain types of smaller unmanned aircraft[9,42]. These regulations are either tailored for UAS, or adapted on a case-by-case basis for specific requirements[18].

Selected examples of national UAS regulatory approaches include:

- **FAA Interim Policy**. The legal basis for civil UAS regulation in the USA is the Federal Aviation Regulations (FAR), and as most UAS do not yet comply with the FAR, the FAA developed an interim UAS policy[3]. With regard to airworthiness, the interim policy requires that all UAS must be airworthy and must conform to the same FAR airworthiness standards that apply to manned aircraft. For the interim, UAS airworthiness approvals will be based on special certificates of airworthiness and continued airworthiness programmes, and the approval processes will mirror the FAA's manned aircraft approval processes. The FAA does, however, acknowledge that UAS requirements may differ from those for manned aircraft, in which case appropriate alternative requirements would need to be defined.

- **EASA Policy Proposal**. In 2005, EASA proposed a policy[2] for the certification of UAS as a first step towards comprehensive UAS regulation. Under European Community (EC) Regulation 1592/2002, as the legal basis, EASA is responsible for the regulation of civil UAS with a maximum take-off mass of 150 kg or more. The regulation of other civil UAS in Europe remains the responsibility of the national civil aviation regulating authorities of EC member states. The policy, which resulted from a joint JAA/Eurocontrol initiative[18], uses existing EASA manned aircraft procedures and includes the issuing of UAS type certificates and certificates of airworthiness. The policy further provides that UAS airworthiness requirements will typically be based on appropriate manned aircraft requirements (EASA "CS" requirements).
- **Joint JAA/Eurocontrol Initiative**. Prior to the publishing of the EASA proposed policy for UAS certification[2], a joint UAS initiative by the JAA and Eurocontrol resulted in a concept for the regulation of civil UAS in Europe[18]. The guiding principles of the concept include fairness, equivalence, accountability and transparency, and the concept emphasises obligations under the Chicago Convention[1] and its Annexes. The concept recommends that existing procedures and requirements, as used for manned aircraft, be applied to UAS. In particular, UAS should be type certified in accordance with existing manned aircraft airworthiness requirements, and should be issued with certificates of airworthiness, the validity of which will depend on the continued airworthiness status of the UAS.
- **UK CAA CAP722 and Light UAS Policies**. In complying with obligations under the Chicago Convention, the main aviation safety requirements in the UK for non-military aircraft are set out in the Air Navigation Order and the Rules of the Air Regulations. As a member state of ICAO and the EU, the UK is responsible for the regulation of UAS of less than 150 kg maximum take-off mass, and other UAS that fall outside the EASA responsibilities. Consequently, the UK CAA developed two UAS policies, CAP 722 and the UK-CAA Policy for Light UAV Systems, covering general UAS certification and operating procedures[4], and light visual

range UAS[19] respectively. UAS operating under CAP722 must meet the same or better safety and operational standards that apply to manned aircraft[4]. Thus, UAS must comply with airworthiness requirements derived from manned aircraft requirements, and must have certificates of airworthiness. Also, continued airworthiness of UAS must be based on similar requirements for manned aircraft. For light visual range UAS, the UK CAA applies a level of regulation that is similar to that for model aircraft[19].

- **Australia CASA Regulations**. Under its Chicago Convention obligations, the Australian legal basis for the regulation of civil aviation is found in the Civil Aviation Act[45] and the Civil Aviation Safety Regulations (CASR)[46]. Specifically, CASR Part 101, Unmanned Aircraft and Rocket Operations, regulates unmanned aircraft and rocket operations[47]. In terms of Part 101, UAS with a maximum take-off mass of 150 kg or more are required to have a restricted or experimental certificate of airworthiness that is issued under CASR Part 21, Certification and Airworthiness Requirements for Aircraft and Parts[48]. UAS with a maximum take-off mass of less than 150 kg are regulated in a similar manner to model aircraft.
- **SA CAA Interim UAS Policy**. The legal basis for the regulation of civil aviation in South Africa is the Civil Aviation Act[49] and the South African Civil Aviation Regulations (SA-CAR)[50], although airworthiness requirements for the type certification of UAS airworthiness are not addressed in the SA-CAR. An interim policy[10] for the approval of civil UAS airworthiness and operations in South African airspace was approved by the South African Civil Aviation Regulations Committee (CARCOM) in 2008 and is awaiting implementation by the SA CAA. This interim policy is a composition of best practices derived from similar international policies and regulations, the results of relevant South African research efforts, and knowledge and experience gained from previous UAS operations in South Africa. For UAS airworthiness, the interim policy provides for both type certified and non-type certified UAS, and recommends the use of tailored existing manned aircraft airworthiness requirements.

3.3.4. Legal Basis for Regulating Civil UAS Operability/Airworthiness

It is evident that the regulation of civil UAS airworthiness is actively being addressed at both international and national levels. It is also evident, however, that the regulation of UAS ***operability***, as defined in Chapter 2 of this thesis, has yet to be addressed in the legal bases for civil aviation regulation.

For the interim, though, the international legal basis for regulating civil UAS airworthiness will remain Annex 8[40] of the Chicago Convention. At national level, the legal basis for regulating civil UAS airworthiness will continue to be found in national legislation and regulations for civil aviation safety.

From a technical perspective, unique UAS airworthiness requirements have yet to be developed and current interim policies generally require that UAS airworthiness be based on airworthiness requirements for manned aircraft, appropriately tailored for specific UAS.

3.4. Legal Basis for UAS Operability Regulation: Military Aviation

3.4.1. Regulation of Military Aviation

It is still generally accepted that the responsibility for assuring military aviation safety is vested in the relevant armed forces at national level. A legal basis for the regulation of international military aviation, similar to the Chicago Convention[1], does not currently exist[9,15], and to mandate and co-ordinate military aviation regulation at international level, such an agreement would be required. Similarly, an "International Military Aviation Organisation" ("IMAO")[15], or equivalent, would need to be established to administrate and implement such an agreement.

A growing trend towards these objectives saw the introduction of an annual International Military Aviation Authorities Conference (IMAAC) in Europe in 2004, and the establishing of a centralised European Military Aviation Authorities Group (EMAAG)[11,51]. The objectives of these initiatives include promotion of safety and sustainability in military aviation, and the promotion of common military aviation regulations and compliance standards[51].

3.4.2. Regulation of Airworthiness in Military Aviation

The formal regulation of military aviation is not yet standard practice[15] and in most countries military airworthiness is managed under a defence department safety programme[52]. A Safety Target Model is used in many such safety programmes, in which the aircraft is considered in terms of its intended missions and operating environments and an overall safety objective, or safety target[18] is set. Critical issues that could adversely affect the safety target are identified in a top-down analysis, and potential risks are deduced in terms of design and operational requirements, using the "as low as reasonably practicable" (ALARP) principle[18,52] for accepting or denying risks. This approach allows the airworthiness authority to focus on the critical safety risks, rather than on the development and implementation of detailed airworthiness requirements, particularly when only a relatively small number of a particular type of aircraft are to be produced.

For each airworthiness project, a Project Safety Case is developed which contains the aircraft configuration and design details, safety requirements and targets, justifications and supporting evidence for the airworthiness of the design, and relevant limitations and instructions to achieve the required safety target[52]. In the United Kingdom, the approval of the Safety Case enables the authorisation of two release documents. The Military Aircraft Release certifies that the Safety Case has been accepted and approved, and the Release to Service authorises regulated operation of the aircraft[52].

The concept of initial airworthiness certification and subsequent continued airworthiness of an aircraft system is employed by the NATO Airborne Early Warning and Control Force Command (NAEW&CFC) to ensure that aircraft systems supplied to it by NATO member countries are airworthy[53]. The initial certification is mandated in an airworthiness policy and is accomplished with the issuance and acceptance of airworthiness certificates of conformance and compliance. The continued airworthiness process follows best practices derived from both the military and civil aviation domains[53].

To ensure mutual recognition of airworthiness between civil and military aviation authorities, some countries have elected to mirror the civil aviation type certification process in the military environment. Examples of countries using this approach include:

- **Sweden**. The Swedish Military Flight Safety Inspectorate (FLYGI) applies Rules of Military Aviation (RML) that are based on European civil aviation regulations, and includes military type certification and a continued airworthiness programme[54].
- **Canada**. The Department of National Defense (DND) and the Canadian Forces (CF) carry out their obligations under the Canadian Aeronautics Act by means of an Airworthiness Programme[55]. Rules and standards are promulgated in a Technical Airworthiness Manual (TAM)[55] and in manuals such as the Airworthiness Design Standards Manual (ADSM)[56]. The TAM prescribes the procedures and minimum requirements for a DND Type Certificate, airworthiness certificates, and continued airworthiness.
- **Australia**. The Australian Defence Force (ADF) applies self-regulation of its military aviation through the ADF airworthiness regulatory system. Similar to the Canadian process, the ADF Airworthiness Manual[57] prescribes the requirements for an Australian military type certificate and service release, certificates of airworthiness and special flight permits, and continued airworthiness.

To address the unique military aviation characteristics more appropriately, an industry study[58] has proposed a hybrid certification approach to resolve various concerns that stem from using either the safety target approach or the type certification approach in military aviation. The hybrid approach utilises the type certification process for those sub-systems of a military system for which airworthiness requirements are commonly prescribed in regulations and industry standards. The safety target approach is used for those sub-systems of the system for which prescribed airworthiness requirements are not defined. Merging the safety target approach with the type certification process enables the accelerated introduction of new and innovative technologies into the aircraft design by concentrating on safety critical issues through hazard analyses and risk reduction programmes[58].

3.4.3. Current Approaches to Regulating the Airworthiness of Military UAS

Although an international legal basis for the regulation of military aviation does not exist, the role of military UAS has evolved to the point where regulation at international level is becoming necessary to allow for the wider spectrum of global operations[42,59]. In anticipation of such international regulation, various military forces have initiated national regulatory programmes for military UAS. For example, the USA Department of the Army Regulation 95–23[60] includes procedures for both national and international Army UAS operations. In the United Kingdom, CAP 722[4] applies equally to civil and military systems, and DEFSTAN 00-970 Part 9[61] describes airworthiness and certification requirements for the design, development and testing of UAS.

France developed military UAV Systems Airworthiness Requirements (USAR)[62], based on the EASA CS-23[63] civil airworthiness requirements, and NATO followed with a specialist team[16] to develop similar draft UAS airworthiness requirements, which were approved for ratification by NATO nations in 2007[17]. The vision of the Swedish Armed Forces is to extend the scope of its existing Rules for Military Aviation (RML)[54] to include UAS, and to retain harmonisation with internationally recognised civil and military aviation regulations[59]. In South Africa, interim UAS airworthiness and operation procedures apply to both the civil and military UAS domains.

3.4.4. Legal Basis for Regulating Military UAS Operability/ Airworthiness

The regulation of military UAS airworthiness is increasingly being addressed at both international and national levels. It is evident, however, as is the case in civil aviation, that the regulation of UAS ***operability***, as defined in Chapter 2 of this thesis, has also not been addressed in military aviation regulation.

However, despite the present absence of international agreements for military aviation and military UAS airworthiness regulation, most national military UAS programmes share the common objective of achieving routine national and cross-border operations in non-segregated airspace[5]. They also share a common regulatory approach aimed at compliance with airworthiness requirements that are equivalent to those for manned aircraft operating in similar airspace[42,58,59]. In Europe, this approach is extended by the European Technology Acquisition Programme to allow a once-off certification of a new design that is accepted by all participating nations[58]. Design certification of a military UAS is to be achieved by means of a military type certificate, which will allow the issuing of a military certificate of airworthiness for the UAS[59].

In summary, therefore, an international legal basis for regulating military UAS airworthiness, similar to Annex 8[40] of the Chicago Convention, does not yet exist. At national level, the legal basis for regulating military UAS airworthiness is found in national legislation and regulations for military aviation safety, when such legislation and regulations do exist.

From a technical perspective, unique military UAS airworthiness requirements have been developed in some cases, while in others UAS airworthiness is based on airworthiness requirements for manned military aircraft.

3.5. Co-ordination and Harmonisation of Aviation Regulatory Systems

Under the Chicago Convention[1], most national civil aviation regulatory systems have been co-ordinated or harmonised[i] since 1944. However, the need for co-ordination of military and civil aviation regulatory systems is also recognised by ICAO, even if only at national level[64].

As military (or 'state') aviation is excluded from the operation of the Chicago Convention, regulation of military aviation, when applied, usually occurs in isolation and is often not effectively harmonised or co-ordinated with other military or civil aviation regulation systems[1,15]. Exceptions do exist, however, as is the case in Sweden. In 1997, the Swedish "Total Aviation System" for civil aviation was adopted as the basis for the development of the Swedish Rules of Military Aviation (RML).

[i] Co-ordination of regulatory systems means ensuring that the regulating intents of two or more regulatory systems, rather than their content, are aligned and have the same end objective. Harmonising of regulations means agreeing, by two or more different authorities, on the minimum content that should effectively be identical in their regulations.

This approach enabled the continued harmonisation of civil and military aviation regulations in Sweden[54].

The drive towards the co-ordination of military and civil aviation regulations is primarily motivated by the continuous growth of the air transportation industry, the growing overlap between civil and military systems, and the increasing cost-driven need for future military aircraft development programmes to be multi-national programmes[53].

The anticipated mutual recognition of licences, certifications and approvals, and the co-ordination and/or harmonisation of regulations may allow for easier integration of military and civil air traffic into a single, non-segregated airspace system. Further, the streamlining of services and the more efficient utilisation of scarce resources may also result from these co-ordination efforts[54].

It must be noted, however, that co-ordination between civil and military systems only is not sufficient, and to advance to equivalence with the civil aviation sector, various efforts in Europe now also focus on co-ordination between different military aviation regulating systems[58]. With the increasing need to also integrate military and civil UAS into non-segregated airspace, the co-ordination of aviation regulating systems will require efforts, at a global scale, similar to those of Eurocontrol in Europe[65,66].

3.6. Industry Programmes: UAS Airworthiness Requirements and Standards

Although industry standards do not have legal status in themselves, most regulatory systems prescribe or refer to industry standards to achieve specific objectives. In support of technology developments associated with UAS, various industry programmes have been established to address the development of means of compliance with airworthiness certification regulations in the form of airworthiness requirements or standards. Organisations such as the European Organisation for Civil Aviation Equipment (EUROCAE), the American Society for Testing and Materials (ASTM), the Radio Technical Commission for Aeronautics (RTCA), the American Institute of Aeronautics and Astronautics (AIAA), the Institute of Electrical and

Electronic Engineers (IEEE), and others, are involved in developing airworthiness and operating standards for unmanned aircraft, onboard systems and supporting systems[9,10,42].

Selected examples of industry programmes include the following:

- **ASTM**. ASTM Committee F38 on Unmanned Aircraft Systems[9] focuses on developing technical publications and standards to primarily address UAS airworthiness, flight operations, and personnel training, qualification and certification[67]. The Committee stakeholders include regulating authorities, industry, professional societies, trade associations and academia, amongst others[67]. Numerous standard specifications, practices and guides have been published, and continue to be proposed and developed, by this Committee[67].
- **EUROCAE**. The European Organisation for Civil Aviation Equipment, EUROCAE, develops standards for European aviation regulating authorities, EUROCONTROL and EASA[9]. In April 2006, EUROCAE established working group WG-73[9] to evaluate existing UAS regulations and standards and to establish required recommendations and technical standards to ensure safe operations of civil UAS in European airspace. Operations (including sense and avoid), air traffic management, airworthiness, and test and maintenance, are the primary focus elements of this working group. Various documents, covering operations of UAS in non-segregated airspace, airworthiness certification and maintenance requirements and requirements for UAS weighing less than 150 kg, have been published by the working group[68].
- **INOUI**. As part of the European Commission Research Program FP6 under the Directorate-General for Energy and Transport (DG Tren), the Innovative Operational UAS Integration (INOUI) project was initiated in 2007 as a "holistic approach" towards integrating UAS into the 2020 European air traffic management system[69]. In respect of airworthiness, "Work Package 3.2" of the project analysed current UAS airworthiness and certification regulations, with the focus on the UAS aircraft (software, hardware and airframe) and the control station. The deliverable report[70] from this work package:
  - describes UAS airworthiness activities in the USA and Europe;

- addresses the common elements and differences between manned and unmanned aviation;
- identifies safety issues related to UAS;
- develops high level safety objectives and requirements; and
- addresses the environmental certification of the UAS, in terms of noise and emissions.

- **RTCA**. The RTCA Special Committee 203 (SC-203, Unmanned Aircraft Systems)[71], is developing performance standards for unmanned aerial vehicle systems, performance standards for unmanned aerial vehicle command, control and communication systems, and performance standards for sense and avoid systems. In 2007, RTCA issued document RTCA DO-304, Guidance Material and Considerations for Unmanned Aircraft Systems[72]. The document is intended to support development of UAS standards through SC-203 and includes a definition of UAS; a description of the UAS operational environment and a top-level UAS functional breakdown. The guidance material provides a framework for developing standards through RTCA Special Committee 203.

3.7. Legal Basis Summary

At international level, the legal basis for regulating civil UAS operability/airworthiness will, for now, remain Annex 8[40] of the Chicago Convention, while at national level, the legal basis exists in national legislation and regulations for civil aviation safety.

An international legal basis for regulating military UAS operability/airworthiness, similar to Annex 8[40] of the Chicago Convention, does not yet exist, while at national level, a legal basis for regulating military UAS operability/airworthiness only exists where national legislation and regulations for military aviation safety exist.

Since an explicitly defined legal basis for regulating UAS operability does not exist, it is recommended that Annex 8 be used as a regulatory reference framework for developing the UAS operability framework.

3.8. Technical Scope of Possible UAS Operability Regulation

3.8.1. Introduction

Although current manned aircraft legislation, where it exists, is utilised and tailored for the regulation of UAS, the objectives of regulating manned aircraft and UAS are not the same[73]. The primary objective of regulating aviation is to ensure safety. The manned aircraft perspective focuses on the safety of the aircraft's occupants, while the focus of regulating UAS should be to avoid injury to people and damage to property as a result of UAS operations, or simply put, "avoid in-flight collisions and avoid uncontrolled ground impacts"[73]. These different perspectives require that the technical scope of regulating UAS be evaluated to ensure their compatibility with current and future UAS regulating objectives. As was discussed in the previous section, current UAS regulating approaches are based on manned aircraft regulations, a trend that will continue until a requirement for a different approach is identified and confirmed. In anticipation of possible future regulating requirements, this section evaluates the technical scope of Annex 8[40] of the Chicago Convention[1], as well as that of a previously-established reference framework for UAS airworthiness requirements[9], in terms of two potential future UAS utilisation scenarios.

3.8.2. Scenario Model

Envisaging the future is at best a challenging exercise. However, various methods exist to reduce some of the uncertainties. For example, "technology timelines" identify possible future technological developments and milestones[74], while a group of science-fiction writers have assisted the USA government in identifying potentially hostile technologies of the future[75]. Future scenario studies provide insight into possible future outcomes of present activities[76,77] and can lead to improved policies and decisions[77]. Scenario studies are, however, based on current perceptions and should be repeated regularly to reflect the impact of actual developments[78].

For the purposes of this study, a UAS scenario study was carried out in which two potential outcomes were developed. The objective of the study was to establish whether current approaches to UAS airworthiness regulation would remain relevant and applicable in terms of possible future requirements. The study was limited to potential developments in UAS-related technologies and applications up to *circa* 2030 - 2040, and it explored possible UAS applications and regulating concepts.

3.8.3. Background to UAS Scenarios

The UAS scenario study was based on the South African-developed "Conversation Model"[76] and was dovetailed with the results of a related USA scenario study[79], in which disruptive civil technologies[ii] were identified that could emerge up to 2025. Two of the technologies were found to be relevant to this UAS scenario study. "Service Robotics" includes unmanned systems as a subset[79], while "The Internet of Things" refers to the concept where objects could become totally accessible and/or controllable via the Internet[79].

Because scenario studies inherently aim at identifying possible outcomes of the future, their development must be based on best possible assumptions of future technologies and developments that are plausible and supportable. It was therefore necessary, by means of an extensive literature survey, to consider developments and trends in technology and regulation, not only in aviation and UAS domains, but also in areas such as space travel, robotics, transportation, computer technologies and artificial intelligence. The results of the survey confirmed possible UAS applications, and enabled the conceptualisation of the two UAS scenarios.

3.8.4. Possible Future UAS Applications

Although current UAS applications are still primarily military, the potential for civil and commercial applications continues to be explored[80]. In developing the UAS scenarios, the following plausible application alternatives for UAS were confirmed:

- military applications;
- public services;
- industrial and commercial civil aviation applications;
- academic, research and development applications; and
- domestic, sport and recreational applications.

[ii] A disruptive technology has the potential to cause significant positive or negative effects in the domains in which it is used.

Military applications include legitimate applications of military UAS, while governments typically carry out public service missions with UAS. Industrial and commercial UAS applications focus on profiteering from UAS, whereas academic, research and development applications use UAS for scientific and social research purposes, as well as for developing new enabling technologies. UAS applications could also, in future, include domestic functions such as personal transportation[74], roaming security surveillance, and automated collection-and-delivery services, while UAS are already considered for aerial sport and recreational activities[81].

In terms of regulation, military UAS would normally fall under the jurisdiction of military regulating authorities, while the remainder of the mentioned UAS applications would generally be subject to civil aviation regulations. As is the case with manned aircraft, regulating authorities would also have to give consideration to unlawful applications of UAS and the effects this could have on future UAS utilisation[79,82].

3.8.5. Enablers

Numerous enablers were identified that will be required for the widespread use of UAS, both in the military and civil aviation domains. The most prominent of these enablers are summarised below.

Enablers in Technology

Various technologies involved in UAS need to advance significantly before UAS can become useful tools in everyday life[79]. Specific technologies that require such advances include:

- **Hardware and hardware elements**. Cost-effective hardware is "extremely important" if UAS are to become more affordable[79]. Materials, systems and equipment specifically suitable for UAS will need to be developed economically, possibly through large-scale application in other fields.
- **Software**. Software platforms are already available but need to become more practical, cost-effective and capable[79]. Standardisation in UAS software and software systems, and possible co-ordination with other relevant industries, such

as robotics, will be essential to reduce development and certification costs and to ensure integration of UAS operations on a global scale.

- **Sensor technologies**. UAS and UAS payloads require a multitude of sensors[79] to carry out their tasks, to operate and to integrate safely into non-segregated airspace. These sensors, and notably sensors for the "sense-and-avoid" function, must be effective, reliable and economical.
- **Wireless communications technologies and networking**. Wireless technologies and infrastructure used for UAS will need to advance substantially to enable improved UAS functionality. Also, increasing numbers of UAS may have to rely on appropriate global networking support systems similar to, for example, the Internet and mobile phone networks. The development of strategies and enabling network facilities could therefore be critical for the expansion of UAS utilisation.
- **Low-cost high-performance energy and powerplant systems[79]**. Longer, more economical UAS flights will always be a primary objective for some UAS applications. To achieve this, suitable energy sources and highly efficient powerplant systems will need to be developed, which may require new related technologies to emerge.

Enablers in Regulations and Standards

It is accepted that civil aviation will remain regulated at international and national levels and that the regulation of military aviation could evolve to the same status. However, the integration of the civil and military regulating functions remain a distant future possibility[64]. Currently, UAS regulation is based on manned aircraft regulations to ensure fairness, equivalence, accountability and transparency[18], and industry standards are being developed to address specific UAS technologies[9,42]. To enable the widespread utilisation of UAS and their safe integration into the airspace system, it is critical that appropriate UAS regulatory systems and relevant industry standards be developed to accommodate current and anticipated future developments.

UAS may be subject to normative rules as it is not only seen as a disruptive technology by the public, but also by non-UAS elements of aviation[2,82]. Normative rules are "moral rules" such as corporate codes of conduct, health and safety regulations, and environmental protection rules[76]. Projects such as the European

"Clean Sky" initiative[83] will undoubtedly impact on UAS and will require associated technological advances in UAS enabling technologies.

3.8.6. Areas of Uncertainty to Monitor

Several areas of uncertainty exist that will influence the development of UAS and UAS enabling technologies. The essential areas of uncertainty to monitor include the following:

- **Military UAS development and implementation**. The development and implementation of military UAS continues to be the dominant and most costly application of UAS. The extent to which military technologies are transferred to the public service and commercial UAS markets may influence the growth of UAS applications in these sectors[79].
- **Engineering**. Significant advances in UAS-related technologies such as sensors, frequency spectrums, communications abilities, security (specifically with large-scale commercialisation), and powerplants, are required to facilitate a significant escalation in UAS utilisation. For example, the development of successful and economical "sense-and-avoid" technologies is critical for any large-scale integration of UAS into non-segregated airspace systems.
- **Reliability, availability and integrity**. Sustained reliability, availability and integrity of UAS and UAS sub-systems must be achieved before UAS can become useful tools alongside manned aircraft.
- **Social and resource issues**. Reluctant public acceptance of UAS remains a concern that may continue to delay public service and commercial UAS utilisation in particular. Also, the unique attributes of UAS may not be sufficient to motivate a large user base, which may limit the sustainability of some UAS industries[79]. In terms of human resources, a shortage of appropriate UAS-unique technical, engineering and operating skills will further limit the capabilities of the UAS industry.
- **Regulation and standardisation**. The rate of developing and implementing effective UAS regulating systems and standards will have a corresponding effect on the rate of deployment of UAS, specifically in the public service and commercial sectors.

3.9. UAS Scenarios

Despite many uncertainties, it is generally accepted that UAS will continue to be utilised for various new purposes. Will this be achieved in the **Classical** manner? Or will **Automation** see new or revolutionary approaches in areas such as UAS operability and operations? The **Classical Scenario** is based on developments that effectively continue the present status and trends in aviation, while the **Automation Scenario** is based on a composition of technologies that are currently being researched and developed, or that are already available, and technologies that are expected to emerge over the next 20 to 30 years. These two scenarios are presented below, with a general vision of future UAS utilisation and concepts for UAS regulation for each.

3.9.1. Classical Scenario

In the **Classical Scenario**, the expected growth in UAS utilisation, and in particular in commercial applications, does not materialise. Development of enabling technologies, and of appropriate legislation and standards, does not progress fast enough and the prolonged efforts required to find sufficient applications to sustain the UAS industry under these circumstances eventually result in many developers abandoning UAS research and development. Except for military applications of UAS, aviation in general remains human-based and automation in aviation is limited to what is typically envisaged in programmes such as the USA's "NextGen"[84] and Europe's "Single European Sky"[65].

Classical aviation industry roleplayers remain the primary product producers and service providers, and civil aviation and most of military aviation remain based on manned aircraft and manned control systems, where technological developments focus on achieving greater performance and environmental protection efficiencies.

Generally, therefore, the structure of the aviation industry remains static and key roleplayers continue to produce primarily manned aircraft products, with UAS being developed and produced mostly for military applications, with limited use in the public service domain. Low-cost manufacturing becomes the critical requirement for the UAS industry to grow.

In this scenario, the Chicago Convention[1] and its Annexes remain the international legal basis for the regulation of civil aviation and are expanded to provide for unique UAS airworthiness requirements. At national level, airworthiness regulations for manned aircraft are mostly tailored on a case-by-case basis to accommodate the regulation of civil UAS. The regulation of civil aviation continues to be based on the 'command and control' style and although some UAS-related regulations become performance-based, the prescriptive approach remains in use.

In military aviation, an international regulating instrument similar to the Chicago Convention does not emerge, and national regulation of military aviation is done primarily internally by armed forces on a voluntary basis, and is limited to the regulation of airworthiness and personnel licensing. Although military aviation regulations, where applied, are manned aircraft-based, more effort is put into developing UAS regulations in response to their greater military utilisation. As military UAS are also deployed increasingly in non-segregated airspace, a degree of co-ordination between military and civil UAS-related regulations is enforced to ensure the safety of civil airspace users.

Technically, therefore, the regulating of the design and approval of UAS continues to be based on the type certification and certificate of airworthiness model used for manned aircraft. UAS-unique regulations are mostly performance-based, and because of the cost involved in the development of standards and the restricted utilisation of UAS for civil and commercial purposes, only a limited number of UAS industry standards come into existence. Finally, the regulation of UAS operability remains focused on regulating primarily those sub-systems of the UAS that affect the airworthiness of the airborne sub-systems of the UAS.

3.9.2. Automation Scenario

The **Automation Scenario** represents a drastically evolved aviation industry in which the UAS becomes a key element of the global transportation system. Significant advances in automation, robotics and enabling technologies allow UAS utilisation to expand rapidly into the commercial market, while UAS that are used for military and public service purposes benefit from technology transfers that result from commercial economy-of-scale developments. Automation knowledge and experience gained in other engineering fields, such as robotic ground vehicles[85], sub-surface robots, automated sea-faring vessels and robotic submarines, are used increasingly in the development of automated UAS.

The classical aviation industry roleplayers remain the primary product producers and service providers for manned aircraft, as well as for most military and public service UAS. On the commercial front, however, industrial robot and radio control model aircraft manufacturers identify "hit applications" for UAS and use economy-of-scale to develop and mass-produce automated UAS for a constantly growing mobility market.

Technological developments focus on achieving greater economy, autonomy, and safety in all sectors of aviation. Automation of UAS and UAS supporting systems is extensive and includes:

- robot based manufacturing;
- automated processes to determine and confirm initial operability;
- autonomous flight;
- automated operations and operational control;
- automated route selection, route management and traffic integration;
- semi-automated occurrence resolution (unless the occurrence is catastrophic); and
- automated processes to maintain continued operability, including onboard health monitoring systems with automated maintenance and repair scheduling and, in most cases, maintenance and repair executed by robots.

Because of safety and liability issues, automation of manned aircraft lags the rapid automation of UAS and is limited to what is progressively accepted by the public.

Due to substantially increased aviation and space activities, the Chicago Convention[1] evolves into a new 'Collective Aerospace Convention', which is the international legal basis for the regulation of manned and unmanned aviation and space operations, both in the civil and military domains. At national level, civil and military aviation are both formally regulated and civil and military regulations each consist of a group of common regulations that apply to both manned and unmanned aircraft, and two groups of additional regulations that respectively address unique manned and unmanned requirements. The regulation of civil and military manned aircraft continues to be based on the 'command and control' style, whereas the advanced technological state of UAS allows a large degree of 'automated regulation'[iii] of UAS. Most regulations are performance- or principle-based and, in terms of the new 'Collective Aerospace Convention', civil and military regulations are co-ordinated to ensure safe operations in all airspace.

UAS regulation becomes database-driven and enforcement is largely automated because of advanced technologies, extensive use of artificial intelligence and automation, and the resulting requirement for rapid regulatory decision making. Continuous online data communications facilitate live oversight, by the UAS operator and the regulating and air traffic controlling authorities, of operability status, operations, route management and air traffic integration. The regulation of UAS operability evolves from type certification and 'certificates of operability', to a process of initial, manual design certification, and continuous online operability monitoring for each unmanned aircraft that is subject to regulation. This process also applies to the regulation of the operability of the UAS as a system, the operability of other airborne sub-systems of the UAS, the operability of its non-airborne sub-systems, and the operability of its functional payloads, where such sub-systems and payloads are subject to regulation. Data from UAS occurrence resolution actions is analysed and used to improve the 'Rules'. The 'Rule Book' is a live and dynamic global database of rules for UAS that is based on the 'Collective Aerospace Convention' guidelines and which is updated both manually and where appropriate, automatically, when occurrence resolutions indicate specific trends that require regulatory intervention.

[iii] In contrast with 'self regulation', which is carried out by the regulated entity, 'automated regulation' remains the responsibility of the regulating authority.

3.9.3. Appraisal of the UAS Airworthiness Regulation Approaches of the Scenarios

A measure of the potential effectiveness of the regulatory processes described in the above scenarios was determined by evaluating the processes against the regulatory concepts and criteria discussed earlier. For comparison purposes, the results of the evaluation are presented with the evaluation results for the current civil and military regulatory processes in Appendix A, Table 1.

The evaluation indicates that the Classical Scenario process will remain favourable for manned aircraft, but may not be as accommodating for UAS, and in particular for public service and commercial UAS operability and operations. In civil aviation, optimising regulations and regulating efficiencies, and improving regulator competencies and accountability remain areas for concern, while military aviation regulation remains limited in effectiveness. The Classical Scenario regulatory process, particularly in terms of UAS operability, is therefore expected to remain mainly acceptable, but with increasing need for reform as new technologies are introduced into the airspace system.

By contrast, the Automation Scenario process is favourable to all sections of civil and military aviation and airworthiness regulation. In addition, although not indicated in Appendix A, Table 1, co-ordination with the space industry is accommodated since this scenario introduces the concept of a 'Collective Aerospace Convention'. It may also be conceivable to apply the regulatory process of the Automation Scenario successfully with limited or no automation in the regulation of UAS, on condition that the collective global aviation regulatory system be reformed and optimised such as to manually achieve the objectives of the Scenario. The Automation Scenario regulatory process is therefore considered to be capable of achieving the status of good regulation, provided that the necessary resources could be applied to ensure the required optimisations and improvements.

3.10. Evaluation of the Technical Scopes of the Scenario Regulatory Approaches

As was the case with regulation, an evaluation of the technical scopes of the regulatory approaches of the two scenarios established a measure of effectiveness of these scopes. For this purpose, the typical layout of regulatory material was used as a basis and a set of airworthiness topics that would satisfy the two scenarios were developed as reference criteria. The current manned aircraft content of Annex 8[40] of the Chicago Convention, and the guidelines contained in the original UAS airworthiness reference framework[9] were evaluated against these criteria, the results of which are summarised in Appendix A, Table 2. Annex 8 was used as reference because it is currently the only international legal basis for aviation regulation, albeit civil aviation. In addition, most recognised civil and military regulatory systems are to a greater or lesser extent based on the airworthiness principles on which Annex 8 is based.

The evaluation indicates that both Annex 8 and the reference framework will be effective for the Classical Scenario, although Annex 8 and its military equivalent, if and when it is established, would need to be expanded to include UAS operability requirements as identified by this study.

With reference to the Autonomous Scenario, both Annex 8 and the UAS airworthiness reference framework[9] will be ineffective in terms of regulating UAS operability in the manner described in the scenario. It is obvious that Annex 8 would not meet the automated regulation criteria for UAS as it was developed for the manual regulation of a specific group of manned aircraft and helicopters. The failure of the UAS airworthiness reference framework[9] to address the scenario criteria is explained by the fact that the development of the framework was based on current manned aircraft and tailored UAS airworthiness requirements and regulatory approaches. The regulation, manual or automated, of UAS operability was not considered during its development[9].

From these results, it is concluded that the regulatory approaches used, and the technical scope applied, in the current and future regulation of UAS operability should not be merely based on manned aircraft equivalents, but should be developed and implemented against the background of constantly updated UAS scenario studies. The two scenarios presented here are considered to represent two typical, but plausible, extremes of UAS developments in the future. Considering these two extremes, it is recommended that the UAS industry and the regulators should anticipate, and prepare for, a UAS future that would be somewhere between the Classical and Autonomous Scenarios.

3.11. Regulatory Domain for UAS Operability

To establish a plausible regulatory domain for a UAS operability framework and criteria, a regulatory approach based on an internationally accepted existing or future legal basis for UAS regulation is required, and the potential technical scope and process of application of the regulatory approach should be defined.

3.11.1. Regulatory Approach

It is recommended that Annex 8 of the Chicago Convention be used as the regulatory approach on which the development of the UAS operability framework and criteria can be based. This arrangement would apply until either Annex 8 is revised appropriately and a military equivalent of Annex 8 is implemented, or until new legal instruments are created that would uniquely address UAS regulation.

The recommendation is based on the following considerations:

- The international legal basis for the regulation of airworthiness in civil aviation is Annex 8 of the Chicago Convention. At national level, airworthiness legislation and regulations are based on the guidance of Annex 8.
- The international legal basis for the regulation of civil UAS operability will, for now, remain Annex 8 of the Chicago Convention, subject to appropriate expansion to accommodate unique UAS operability requirements.
- The civil aviation regulation process was found to be in need of reform, specifically in terms of addressing new technologies, such as UAS.
- The regulation of military aviation was found to be in need of significant initiatives if it is to gain an equal standing with its civil counterparts.

- There is currently no international legal basis for the regulation of military aviation and at national level, the regulation of military airworthiness in particular is only gradually starting to gain wider acceptance. The regulation of the airworthiness, and to some extent the operability, of military UAS is done in a similar manner to the regulation of military manned aircraft, except that for UAS, cognisance is also taken of civil aviation requirements to assure authorisation of operations in civil airspace, when required.

3.11.2. Technical Scope and Application of Regulatory Approach

With regard to the technical scope and the application of the regulatory approach, the following were identified:

- Although Annex 8 of the Chicago Convention and the original UAS airworthiness requirements framework[9] are considered to provide substantive guidance for UAS operability criteria, the UAS scenario study indicated that technically, both these sets of guidelines do not effectively address the total scope of UAS operability.
- Both the UAS industry and UAS operability regulators should consider conducting regular scenario studies to identify developments and trends that could have significant effects on the development, utilisation and regulation of UAS in the future.
- The regulation of UAS operability must not only be based on manned aircraft requirements and currently perceived UAS-unique requirements, but must also provide for the future emergence of new and novel technologies.
- The regulation of military UAS operability should be co-ordinated with civil requirements, but should not necessarily be harmonised with them, in order to accommodate military-unique conditions.
- Both civil and military aviation regulators should consider the application of a hybrid airworthiness/operability certification approach to enable rapid introduction of new technologies.
- Although it is more likely that manual regulation of UAS operability will continue for many years, the concept of a degree of automated regulation should not be disregarded and regulators should at least investigate potential requirements for, and implications of, operability regulation carried out in this manner.

From these considerations, it is concluded that a generic technical scope for UAS operability should be developed which would apply to both civil and military UAS, and which would be usable in both the engineering and regulatory domains. Regulating authorities should also consider modernising the process of regulating UAS to optimally utilise emerging technologies in the interests of more efficient and safer utilisation of the available airspace.

3.12. Summary

In this chapter the background for establishing a plausible regulatory domain for UAS operability was investigated. An overview of general regulatory concepts was given, and international and national approaches in aviation regulation were described, including trends in UAS airworthiness regulation.

An appropriate regulatory approach and the potential technical scope for UAS operability regulation were identified, and the process of regulation was evaluated by means of a UAS scenario study. Finally, a regulatory domain for UAS operability was recommended, based on the selected regulatory approach and the required technical scope and process for UAS operability regulation.

Within the scope of this regulatory domain, therefore, an appropriate UAS operability framework and criteria can be developed. This confirms that the second research question of this study has been satisfactorily addressed.

The research design and methodologies that were used in this study to develop the UAS operability framework and criteria are described in the next chapter, which is followed in the subsequent chapter with a discussion of the results that were achieved with the research and development work.

4. RESEARCH METHODOLOGY AND DESIGN

4.1. Introduction

This study focuses on the establishing of an appropriate UAS operability framework and criteria, and the process that was applied to answer the research questions of the study is described in this chapter.

4.2. Research Method

The study is mainly a qualitative study and is based on the development type research approach. Qualitative research can be described as the utilisation of qualitative data to understand and explain social characteristics[86]. In qualitative research, the researcher selects an appropriate approach in which the research will be conducted. For this study, the development type research was selected with the objective to make a contribution in both the practical and scientific realms[86]. The practical contribution of this study is comprised of the UAS operability framework and the UAS operability criteria with which the framework was validated, while the scientific contribution is found in the unusual approach of applying engineering analysis and development methods to legislative material to develop the UAS operability framework and criteria for use in the engineering domain.

4.3. Research Design

The tools and techniques that were used during the study included an exhaustive study of existing material, the analysis of the results of the studied material, the innovative development of the UAS operability framework and criteria, and the critical evaluation of the results.

4.4. Airworthiness-related Literature Study

In developing the original UAS airworthiness requirements framework[9], an extensive literature study was conducted to identify and collect appropriate and relevant airworthiness-related material.

The initial survey focused on the manned aircraft and UAS domains in terms of regulatory requirements for airworthiness. However, in applying engineering analysis principles and considering a wider scope of literature, a very unique and unusual, but appropriate, alternative source of reference material was identified and utilised. These alternative references were found amongst the USA FAA reusable (space) launch vehicle (RLV) regulations and technical reports.

4.5. Reusable Launch Vehicle Flightworthiness Literature Study

Despite the fact that an RLV is used for flight into space, the typical RLV system is remarkably similar to a typical UAS in terms of system composition (airborne, non-airborne and payload sub-systems). The initial airworthiness-related literature survey revealed, however, that the body of proven and substantiated knowledge that already exists for RLVs in the form of regulations and technical reports, had not been exploited in the development of UAS policies and regulations.

The survey of the RLV material confirmed that the similarities between an RLV and a UAS extended beyond system level and it was elected to include relevant RLV reference material in this study. The results of the RLV literature survey were analysed and compared with typical existing manned and unmanned aircraft regulations, and appropriate RLV flightworthiness criteria were identified for mirroring in the original UAS airworthiness requirements framework[9]. Subsequently, the RLV flightworthiness material proved equally applicable to the development of the UAS operability framework and criteria.

This study therefore not only utilised the obvious and traditional airworthiness reference material from the manned aircraft and UAS environments, but also explored the realm of space travel regulations in the form of RLV flightworthiness criteria. The use of this previously untapped, yet proven, source of operability-related information enabled the significant expansion of the scope of the UAS operability framework and criteria to address the safe and reliable functioning of the complete UAS and its sub-systems, rather than just its airworthiness.

4.6. Data Analysis and Product Development

Relevant data obtained from the literature studies were evaluated, analysed and consolidated in terms of applicability to the development of the UAS operability framework and criteria. The first product resulting from this process was the original UAS airworthiness requirements framework which was subsequently peer-reviewed and published[9].

Continued analysis of related engineering and regulatory reference material, and the analysis of potential future UAS utilisation scenarios, confirmed that the original UAS airworthiness requirements framework[9] would be a valid tool, if the operability of UAS were to be restricted to the scope of manned aircraft airworthiness regulations. However, in this continued analysis process, various aspects were identified that needed to be addressed or improved if the original framework[9] was to be developed into a representative and generic UAS operability framework.

From the above process and results, the UAS operability framework and criteria were developed. In the development of the criteria content, existing manned aircraft and UAS airworthiness guidelines and regulations, RLV flightworthiness guidelines and regulations, and sound engineering innovation, extrapolation and judgement were used to create the criteria such that they would be generic and applicable to the engineering domain, while remaining compliant with the scope of the regulating domain.

4.7. Critical Evaluation

Following the studying and analysis of existing material, and the development of the UAS operability framework, a critical evaluation is required to test the validity and usability of the framework.

The critical evaluation started with the peer review of the original UAS airworthiness requirements framework[9] which identified various improvements to enhance the usability of that framework.

The evaluation process continued with further critical analysis of the original UAS airworthiness requirements framework[9] and an initial review of potential criteria that would be applicable to the operability of a UAS and its sub-systems. This process identified the shortcomings in the original airworthiness requirements framework[9] which resulted from considering only manned aircraft regulations and existing UAS airworthiness requirements.

By consolidating the required framework improvements from these previous evaluations, and including the results of the further research and analysis work that was carried out, the UAS operability framework was formulated.

The critical evaluation of the UAS operability framework was accomplished by validating its structural content. This was done by populating the framework with criteria that were developed to address all operability-significant issues of a UAS as a system, as well as of its airborne, non-airborne and payload sub-systems. This process confirmed that the UAS operability framework structure is appropriately generic and has sufficient scope to facilitate relevant operability issues for UAS.

4.8. Limitations of study

This study focused on producing a UAS operability framework, and validating the framework with UAS operability criteria, for use by the engineering domain. The objective of this study was not to develop detailed engineering specification-level requirements for UAS.

As its scope was limited to the engineering domain, the study also did not develop regulatory requirements for UAS, although its results could be used as guidance material by UAS regulating authorities in the development of such detailed regulations.

Since the utilisation of UAS is not yet on the same level as that of manned aircraft, it follows that existing knowledge in respect of the research questions is still limited, although not stagnant. In defining the UAS regulatory domain, this study therefore had to consider the results of a scenario study, the continued accuracy and validity of which will need to be constantly monitored to ensure that the results of this study are revised and enhanced accordingly.

4.9. Summary

In this chapter, the research design and methodologies used were described, the development and evaluation tools that were used in the study were discussed and the limitations of the study were identified.

In the next chapter, the development of the UAS operability framework is described.

5. DEVELOPMENT OF THE UAS OPERABILITY FRAMEWORK

5.1. Introduction

The third research question of this study asks: Can a generic UAS operability framework, within the scope of typical aerospace regulatory frameworks, be developed to address the operability criteria and requirements for UAS, their airborne sub-systems, their non-airborne sub-systems and their payloads?

The process of developing the UAS operability framework consisted of several phases. In the first phase, the original UAS airworthiness requirements framework[9] was developed and published for peer review. The next phase incorporated the recommendations received in respect of the original framework into the development process, and included further significant research, analysis and development of relevant framework content, aimed at identifying an appropriate structure for the operability framework. The final phase required the validating of the operability framework by means of populating the framework structure with appropriate operability criteria. This validation process identified further areas that required re-structuring and refinement, and following the necessary revision of the framework, the UAS operability framework was finally completed.

This chapter describes the development process of the UAS operability framework in terms of these phases.

5.2. Phase 1: Development of the Original UAS Airworthiness Requirements Framework

The initial research of this study focused on the airworthiness regulation approaches that were prevalent at the time, and in particular in respect of manned aircraft and UAS. In addition, flightworthiness regulations and requirements as applied in commercial space transportation for reusable launch vehicles (RLVs) were identified as a unique and relevant source of reference material for UAS airworthiness requirements. Using relevant information from the initial research results, the first product of this study was developed in the form of the original UAS airworthiness requirements framework[9]. This original framework is reproduced in Appendix A, Table 3[9].

The original framework achieved the following[9]:

- Current best practices in airworthiness and flightworthiness regulation were analysed and consolidated into a single airworthiness requirements framework.
- The framework is generic in nature and is not limited to specific UAS types or categories. However, its scope is limited to the airworthiness of the aircraft and the 'airworthiness' of the remote control station.
- The framework is based on Annex 8[40] of the Chicago Convention[1], the French DGA's USAR[62], as well as appropriate airworthiness and flightworthiness requirements derived from relevant reference material for manned and unmanned aircraft, and RLVs.
- The framework can be utilised both in the engineering and regulating domains and applies equally to civil and military UAS.
- The development of the framework identified the requirement for further research to establish airworthiness requirements for unique UAS aspects that had not been addressed before.

5.2.1. Conceptualising the Original UAS Airworthiness Requirements Framework

Primary Objectives

The primary objectives for developing the original UAS airworthiness requirements framework[9] were to achieve a generic approach to determining detailed UAS airworthiness requirements, and to ensure that the scope of the approach would apply to regulated and unregulated, military and civil UAS.

Development Process

An engineering analysis approach was used to develop the original framework[9]. A thorough analysis of existing material was done and was followed by the evaluation and selection of appropriate airworthiness elements to formulate the framework. The process that was followed is illustrated in Figure 5.1 and described in the following paragraphs.

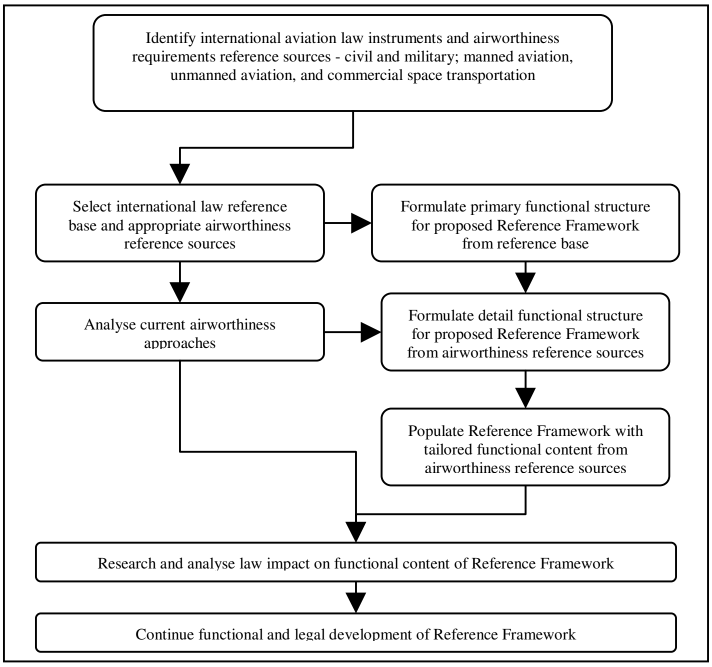

Figure 5.1: Development process for formulating the original UAS airworthiness requirements framework[9]

- **Analysis of Existing Airworthiness Material**. The framework was based on reference material that covered[9]:
  - manned aircraft airworthiness regulations and regulatory compliance standards, and in particular Annex 8[40] of the Chicago Convention[1];
  - existing UAS airworthiness regulations and airworthiness guidelines, with the French DGA's USAR[62] as the primary reference; and
  - flightworthiness regulations and guidelines for reusable launch vehicles (RLVs).

The French DGA's USAR was selected as the primary reference for the following reasons:

- it was one of the first UAS-unique regulations that contained specific and detailed airworthiness requirements;
- it was developed for military application, but was based on the typical layout of civil airworthiness regulations, in this case EASA's CS-23[63] requirements for light manned aircraft;
- it contains airworthiness requirements in regulatory format, rather than prescriptive standards such as are typically contained in industry standards and military standards such as the UK DEFSTAN 00-970 Part 9[61]; and
- the approach used in its development (tailoring of existing airworthiness requirements that "*leads to define an airworthiness norm at least*

equivalent to minimal airworthiness requirements applicable to manned general aviation aircraft"[62]) was subsequently also used in the development of NATO's USAR ("*The intention of this document is to correspond as closely as practicable to a comparable minimum level of airworthiness for fixed-wing aircraft as embodied in documents such as 14 CFR Part 23 and EASA CS-23 (from which it is derived) whilst recognising that there are certain unique features of UAV Systems that require particular additional requirements or subparts.*")[17], and endorsed the approach selected for the development of the original UAS airworthiness requirements framework.

- **Formulating the Framework Structure**. The structure of the framework was derived mainly from the layouts of Annex 8[40] of the Chicago Convention[1] and the French DGA's USAR[62]. The framework was further enhanced with appropriate elements from the structures of published UAS airworthiness regulations and requirements, as well as the structures of flightworthiness regulations and guidelines for RLVs[9]. This approach was selected to ensure the highest level of commonality with existing airworthiness regulations and requirements, and to ensure that the objectives of generality and sufficiently broad scope for the framework could be achieved.
- **Framework Parts**. The structure of the original framework consists of the following higher-level Parts:
  - Part I: Definitions and Classifications, in which terminology with specific UAS interpretations are addressed, as well as the classification of UAS. This Part has particular significance for the regulating domain.
  - Part II: Procedural Requirements, in which procedures are described that are required to effectively administrate the UAS airworthiness process. This Part usually also has particular significance for the regulating domain. However, this Part should be included in UAS airworthiness/operability frameworks that are used in the engineering domain in order to ensure that the procedures applied by the engineering domain are co-ordinated with the regulating domain procedures.
  - Part III: Unmanned Aerial Vehicle and System Airworthiness Requirements, in which the technical elements of airworthiness

requirements are addressed. The structure of this Part is based on the French DGA USAR[62] structure, which follows the typical manned aircraft airworthiness requirements structure but with the added element of the UAS remote control station.

- **Framework Sections**. The structure of each Part, consisting of 'Sections', was developed from the analysis and co-ordination of relevant existing reference material. This process entailed the evaluation and comparison of the reference subject material for each element that was to be potentially addressed in the framework. Appropriate subject material was then consolidated and, based on the consolidated subject material, relevant subject elements for the Sections of each Part of the framework were derived. The Sections are shown in Appendix A, Table 3.

  The value of considering RLV flightworthiness material became evident in this phase as various subject elements, and subject material, were identified from the RLV material that were not covered in existing manned aircraft or UAS references, but which form necessary and essential elements of the airworthiness requirements for UAS.
- **Framework Sub-Sections**. Subsequent to identifying the Parts of the framework, as well as the Sections of each Part, a similar process was followed to create the Sub-Sections for each Section and again, RLV flightworthiness material was invaluable in addressing the voids in existing manned aircraft and UAS airworthiness material. The Sub-Sections are shown in Appendix A, Table 3.

5.2.2. Significance of the Original UAS Airworthiness Requirements Framework

The significance of the original framework is found not only in the consolidation of existing airworthiness regulations and requirements, but is also found in the scope of the framework which was enhanced with essential elements that were derived from relevant RLV flightworthiness requirements. This enhancement was achieved as follows:

- During the primary study of existing airworthiness material, the existence of a significant number of accessible engineering and regulatory references for RLVs, published in the United States of America (USA), was established. A search for similar material from other space transportation agencies was not successful.

- An analysis of the USA Federal Aviation Administration (FAA) regulations for RLVs, an FAA guide to RLV software and computing system safety, an RLV operations and maintenance approach proposed by the USA Research Triangle Institute (RTI), and an American Institute of Aeronautics and Astronautics (AIAA) guide to safety critical hardware for RLV developers, were analysed[9]. Of particular importance is the fact that the FAA regulations are generic in nature and do not address a particular type or category of RLV.
- The relevance of the RLV flightworthiness model to UAS airworthiness was established from a comparison of the attributes of RLVs and UAS[9]. Unlike manned aircraft, but similar to UAS, an RLV system consists of the airborne sub-system (the launch vehicle), its non-airborne and other airborne support sub-systems, and its payload, and can be manned or unmanned. An RLV is launched, performs its mission, and returns to its base for preparation for a next launch, similar to a UAS. Thus, the relevance of the RLV model to UAS is found in the similarities between their systems, sub-systems and their operational phases, but specifically also in the fact that RLVs can be operated as unmanned vehicles.
- Finally, appropriate airworthiness requirements uniquely relevant to UAS, and not normally found in manned aircraft or existing UAS airworthiness requirements, were derived from the RLV results, and included in the original framework.

The inclusion of the airworthiness requirements derived from the RLV material therefore contributed to the completeness of the scope of the original framework and provided guidance for generalising the framework. The RLV material was also instrumental in identifying specific areas of flightworthiness and airworthiness importance that had previously not been considered in the traditional airworthiness approaches[9].

5.2.3. Further Research Recommended

Although the original framework was a significant contribution towards establishing generic UAS airworthiness requirements, various aspects were identified that required further research and investigation. The following issues were considered to have had the highest priorities[9]:

- detail requirements for hazard and collision avoidance capabilities;
- definition of minimum required emergency and flight termination capabilities;
- scope and details of airworthiness requirements for various levels of autonomous flight;
- requirements for control stations, both airborne and non-airborne;
- requirements for ground support equipment unique to UAS;
- continuous airworthiness requirements, and in particular for UAS involved in long-endurance operations;
- airworthiness-related requirements for UAS security; and
- requirements to address the influence of human factors on UAS airworthiness.

As part of the validation process of this research, the peer review process of the original framework[9] confirmed the need for further research of these issues. The subsequent development of an improved framework as the next step of this study therefore became essential and the development of the 'UAS operability framework' was initiated.

5.3. Phase 2: Development of the UAS Operability Framework

5.3.1. Introduction

In the previous section it was shown that, in comparison with existing airworthiness requirements for manned aircraft and UAS, the development of the original UAS airworthiness requirements framework[9] resulted in a more comprehensive and generic framework for UAS airworthiness requirements.

This was achieved by consolidating existing airworthiness requirements for manned aircraft and UAS, and specifically, by enhancing the scope of the framework with material derived from RLV flightworthiness requirements. However, it was also established that additional research would be required to further improve and enhance the original framework. In other words, the development of an acceptable UAS operability framework had not been achieved with the original framework, even though the original framework is recognised as a significant contribution to UAS airworthiness guidelines[9].

To progress with the development of the UAS operability framework, a process of further detailed analysis, critical evaluation and innovative improvement of the original framework was initiated to address the aspects that were identified for further research. This process was also required to identify any other shortcomings of the original framework[9], as well as any additional aspects that would need to be addressed to achieve the objectives of this study in respect of the UAS operability framework and criteria.

The process that was therefore followed to develop the UAS operability framework included the following steps:

- A critical evaluation of the original airworthiness requirements framework[9].
- Definition of the structure of the UAS operability framework on the basis of the results of the critical evaluation of the original framework, and the results of the improvement process.

These steps are discussed in more detail in the following sections.

5.3.2. Critical Evaluation of the Original UAS Airworthiness Requirements Framework

The original UAS airworthiness requirements framework[9] was based primarily on Annex 8[40] of the Chicago Convention[1] and the French DGA's USAR[62], with additional enhancements derived from other existing UAS airworthiness regulations and requirements, as well as from regulations and guidelines for RLVs[9]. This approach ensured basic commonality with existing manned aircraft and UAS airworthiness regulations and requirements, while also ensuring the enhancement of the scope of the framework with content based on RLV guidelines.

A general evaluation of the original framework revealed the following:

- The original framework focuses on achieving an acceptable level of airworthiness, rather than operability, of the aircraft and 'offboard' equipment that is limited to the remote control station, in order to comply with the perceived and anticipated future regulatory approaches and requirements for UAS. In view of the introduction of the concept of UAS operability, it is clear that the original framework fails in addressing the operability of a generic UAS with airborne and non-airborne sub-systems, as well as payloads.

- The layout of the original framework is essentially representative of the layout used in regulatory requirements and the approach used to develop its contents mirrors typical regulatory approaches. The UAS as a system and significant UAS sub-systems, such as airborne sub-systems other than the aircraft, non-airborne sub-systems other than the remote control station, and the payloads carried on board the aircraft, are not addressed as such in the original framework. Unless the user of this original framework has a thorough knowledge and understanding of its contents and purpose, the significance and inclusion of these sub-systems could be overlooked in an engineering study, and indeed, even in the compilation of regulatory requirements.
- An evaluation of the contents of the original framework[9] in respect of the objectives for the UAS operability framework provided further requirements for improvement. In addition to this critical self-analysis of the original framework, recognition was also given to the peer review recommendations to the published framework[9], as well as to workgroup, industry and public responses received during the drafting of the 'Interim Policy for Civil Unmanned Aircraft Systems in South Africa'[10].

In respect of the structure of the original framework, and in terms of the revised objectives of this study, as described in Chapter 1, the findings and recommendations that resulted from the critical evaluation identified the following:

- Part I, Definitions and Classifications, of the original framework was intended for UAS-specific terminology and UAS classifications, mainly for regulatory use. In its present form, these topics remain valid, but the objectives and approach of this part should be revised to be applicable to the engineering domain.
- Part II, Procedural Requirements, describes the administrative processes to achieve airworthiness approval for a UAS within the scope of the traditional regulated airworthiness programmes. This part emphasises the administrative

processes that are typically applied in regulating the airworthiness of manned aircraft and UAS. To be applicable to the engineering domain, however, this part should be revised to address relevant administrative processes, from an engineering perspective, to ensure UAS operability.

- Part III, Unmanned Aerial Vehicle and System Airworthiness Requirements, of the original framework includes topics for airworthiness requirements that were derived mainly from manned aircraft and existing UAS airworthiness regulations and requirements, and enhanced with material from RLV flightworthiness regulations and requirements. Although the framework consolidates a wide spectrum of airworthiness topics, the focus of this part is limited mainly to typical regulated airworthiness requirements. For the purposes of this study, therefore, this part should be revised to reflect an engineering approach. This part should further be revised to address the operability of the UAS as a system, as well as the operabilities of the UAS sub-systems and its payloads. To achieve this in a clear and unambiguous manner, this part should be sub-divided into sub-parts to separately address the operability requirements for the UAS as a system, for its airborne sub-systems, for its non-airborne sub-systems and for its payloads.

In summary, therefore, the critical evaluation established that, although the original UAS airworthiness requirements framework[9] represented a significant advancement in establishing comprehensive and generic UAS airworthiness requirements, it only partially satisfies the objectives for the UAS operability framework. In fact, a significant revision of the original framework would be required if the complete operability spectrum of a UAS and its sub-systems were to be addressed in the UAS operability framework.

5.3.3. Defining the Structure of the UAS Operability Framework

In the process of developing the UAS operability framework, two approaches towards defining the framework structure were identified:

- The original UAS airworthiness requirements framework could be subjected to a revision process that would accommodate the relevant predetermined recommendations and improvements, but which would essentially retain the typical regulatory approach, structure and content.

Alternatively,

- The essence of the original framework could be used as a reference model for constructing a significantly different, improved and expanded operability framework. However, although this new operability framework would still recognise regulatory approaches, it would be a unique innovation in that it would be the first such framework to be explicitly developed for the UAS engineering domain.

Since UAS operability was defined in answering the first research question of this study and a regulatory domain was identified for the second research question within which the UAS operability framework could be developed, it would clearly be feasible to apply the second option for developing the framework structure. Although this would require a substantial departure from traditional regulatory and airworthiness approaches, the following motivations effectively endorsed using this option:

- One of the primary purposes of this study was to develop a generic and comprehensive UAS operability framework for the engineering domain, not for the regulatory environment. The framework should therefore address engineering issues that would ensure the safe and reliable functioning of a UAS, whether it is regulated or not.
- The framework is intended to be used as an index and a guideline for the development of relevant UAS engineering processes and procedures. Thus, for a particular UAS under consideration, the UAS development engineering team would follow the primary structure of the framework and select applicable operability topics. For each selected topic, the topic's associated operability criteria are applied to develop appropriate engineering processes, procedures and UAS requirements for the system. The UAS operability framework and criteria to be developed must therefore be appropriate for use and application in the engineering of UAS. By retaining a regulatory approach as in the original framework, the new framework and its contents would include material that is relevant in the administration and enforcement of regulations, but which would be inappropriate and confusing in the engineering domain. A new framework can be structured to address only the relevant engineering issues.

- To ensure that the UAS operability framework leads to engineering work that would be acceptable for compliance with regulations, the framework would not ignore the regulatory model of the original UAS airworthiness requirements framework, but would apply only the topics that are relevant to engineering processes.
- Restructuring the framework to make provision for the UAS as a system, as well as for the UAS sub-systems, would in any event require a significant change in the structure of the original framework.
- The content of the UAS operability framework must be suitable to allow the derivation and development of relevant engineering processes, procedures and UAS requirements from it by the engineering domain. Regulatory style material, as was intended for inclusion in the original framework, would require considerable interpretation to become useable.

Based on the above, it was decided to use the essence of the original framework as a reference tool, and to construct a new, improved and acceptable UAS operability framework structure. Therefore, the new UAS operability framework still recognises regulatory approaches and requirements, but is developed explicitly as a unique, first such framework for the UAS engineering domain.

The structure of the UAS operability framework was defined as follows:

- The structure of the original UAS airworthiness requirements framework was critically evaluated, from which relevant engineering topics were identified and irrelevant regulatory-related items were removed.
- A new structure for the framework on three different hierarchical levels was developed to make provision for UAS definitions and classifications, procedural requirements for UAS engineering to ensure regulatory compatibility, when required, and operability criteria for UAS, their sub-systems and their payloads.
- An initial evaluation of the new structure was carried out against prototype material for the fourth hierarchical level of the framework, from which further improvement and refining of the top three levels of the structure followed.
- The final structure of the UAS operability framework followed further refinement that resulted from the validation process which was applied to the framework.

The characteristics of the final UAS operability framework structure include the following:

- The framework is divided into three primary parts, with each part being sub-divided into sub-parts, sections and sub-sections, as required.
- The framework is generic and comprehensive, and is not limited to a specific type or category of UAS.
- Part I of the framework makes provision for the inclusion of definitions and classifications in the engineering requirements, specifications and documentation for a particular UAS under consideration. The scope of the topics mirrors the equivalent part in the original UAS airworthiness requirements framework, but its application is in the engineering domain only.
- Part II consists of procedural criteria that should be applied in the engineering domain to ensure compliance with regulatory requirements, when the UAS under consideration is subject to regulation. The equivalent part of the original framework was used as reference material in developing these procedural criteria.
- Part III includes the operability criteria for UAS as systems (Part IIIA), for their airborne sub-systems (Part IIIB), for their non-airborne sub-systems (Part IIIC) and for their payloads (Part IIID).
- Part IIIA is a new part introduced into the framework and is unique in that it addresses the operability of the UAS as a system in terms of a systems engineering approach. Traditional air- and flightworthiness requirements typically address a particular type of product (aircraft, engines, propellers, a weapon system and reusable launch vehicles, among others), but seldom contain requirements for a complete system such as a UAS and its sub-systems. In this part, the UAS is considered to be a 'system of systems', and appropriate UAS-specific operability criteria were developed from reference material used by the United States Department of Defense[87] and NASA[88].
- Part IIIB includes operability criteria for the airborne sub-systems of a UAS. Although this part was developed from the equivalent part in the original framework, it does not limit the operability criteria to aircraft only, or to specific types or categories of aircraft, but makes provision for other airborne sub-systems

of the UAS that are also essential for ensuring the safe and reliable functioning of the UAS as a system.

- Part IIIC is again a new part in the framework and covers all the non-airborne sub-systems of the UAS under consideration that are also necessary, in addition to the airborne sub-systems, to ensure the safe and reliable functioning of the UAS as a system. The non-airborne sub-systems are not limited to remote control stations only, but make provision for any other non-airborne system support sub-systems. In addition, non-airborne sub-systems are not considered to be ground-based only, and could be water-based, based on seafaring vessels, submarine based, building based or man-carried, amongst others. The 'airworthiness' material for remote control stations contained in the original framework was used as reference material, where relevant, in the development of the remote control station operability criteria.
- Part IIID is a new part and includes operability criteria for the payloads that are to be carried by the UAS. The part is unique in that it is not limited to functional payloads only, but also makes provision for cargo payloads, and for internal and external payloads. The payloads do, however, exclude human passengers and live animals.
- In order to establish a significant level of consistency in the structure of the framework, the topical layouts of Parts IIIB, C and D were kept similar as far as was practicable. For the purposes of defining the framework structure, the framework hierarchy was developed from part level to sub-part and section levels.

Based on the above, and including the further refinements that followed from the framework validation process, a final version of the UAS operability framework was produced and is included in Appendix B, Table 1 for reference purposes.

5.4. Phase 3: Summary of the Validation of the UAS Operability Framework

5.4.1. General

Although the UAS operability framework was developed in part to achieve the research objectives of this study, its value and contribution to the UAS knowledge base had to be more substantial and significant than the creation of a useful engineering index of UAS operability criteria. In addition, the framework had to be demonstrated to be useful as an engineering tool in its relevance, comprehensiveness and generalised character. Thus, a suitable evaluation process had to be applied to the framework to satisfy these challenges.

After considering several options, it was decided to validate the UAS operability framework in terms of its relevance, comprehensiveness and generalised character by expanding its hierarchy to a fourth level (sub-section level) and by populating the framework with operability criteria developed specifically for each sub-part, section and sub-section of the framework, as applicable. The topics that were included in the sub-section level of the framework, as well as the operability criteria, were subsequently evaluated to establish whether the framework was indeed relevant, comprehensive and generic, by judging whether the framework and criteria could be applied to any type of UAS, whether regulated or not. It was also necessary to determine whether the framework could be applied independently to any UAS sub-system (airborne, non-airborne or payload), and whether the criteria could be applied in the UAS engineering domain to develop specification-level UAS engineering development requirements.

In addition to validating the framework in respect of its relevance, comprehensiveness and generalised character, the evaluation process also identified further framework refinements that were required and which were subsequently implemented in the final UAS operability framework, as well as in the populated framework.

The process of evaluating and validating the UAS operability framework was completed successfully and the populated framework is presented in Appendix C, Populated UAS Operability Framework Tables. The operability framework, as well as the operability criteria with which it is populated in Appendix C, were found to be relevant, comprehensive and generic, and were also found to provide appropriate and relevant criteria from which engineering requirements for the development of UAS can be developed and implemented to ensure the safe and reliable functioning of UAS.

5.5. Chapter Summary

In this chapter, the background and development process of the UAS operability framework was described. The original UAS airworthiness requirements framework was evaluated to establish its shortcomings, the development of a new structure for the UAS operability framework was described and the process of validating the new framework was summarised. In respect of the objectives of this study, the third research question had been successfully addressed.

In the next chapter, the fourth research question is addressed with a detailed description of the validation of the UAS operability framework.

6. VALIDATING THE UAS OPERABILITY FRAMEWORK

6.1. General

To answer the fourth and final research question of this study, this chapter must show that the operability framework can be validated by populating it with appropriate, generic UAS operability criteria from which the engineering domain can develop relevant engineering requirements for the operability of a specific UAS, its airborne sub-systems, its non-airborne sub-systems and its payloads.

In the previous chapter it was stated that although the UAS operability framework was developed to achieve specific objectives, its value and contribution to the UAS knowledge base had to be shown to be more substantial and significant than just an index of operability criteria. In addition, the framework had to be demonstrated, by applying, utilising or evaluating its structure, to be useful as an engineering tool in its relevance, comprehensiveness and generalised character.

Different options to address the research question and to determine the usefulness and contribution of the framework were considered, including applying the framework to existing UAS, utilising the framework to develop specific UAS operability requirements, and validating the structure of the framework by populating it with operability criteria.

The first option required the application of the framework to at least two different, existing UAS to establish the value and usefulness of the framework. This option was not considered as it would have only demonstrated the level of usefulness of the framework in respect of the specific UAS that were selected, but its relevance and usefulness in totality would have remained unanswered.

The second option would utilise the framework to develop specific UAS operability requirements by populating the framework with material derived from air- and flightworthiness requirements, in a similar but condensed format as is used for airworthiness requirements. The implementation of the second option was initiated, but almost immediately terminated, because the populating material became summaries of regulatory-style material, rather than operability criteria developed specifically for the engineering domain.

The second option did, however, lead to an effective evaluation process for the framework. The resulting process, called the 'validation process' for the purposes of this study, would evaluate the relevance, comprehensiveness and generalised character of the framework and, if the evaluation was found satisfactory, would validate the structure of the framework.

6.2. Validation Process

The validation of the UAS operability framework was carried out by concentrating on whether it was possible to populate the framework with reasonable and relevant UAS operability criteria, and whether the populated framework would remain sufficiently generic and comprehensive to still be useable for the engineering development of any type of UAS.

In the first step of the validation process, the framework was first expanded to a fourth hierarchical level to include sub-sections in all relevant third-level sections of the framework. The sub-section details are included in Appendix B, Table 1.

The next step involved the development of criteria to populate all sub-parts, sections and sub-sections of the framework, as appropriate. The criteria were developed from best industry practices, where such practices could be found in regulatory and engineering literature, or were newly developed by applying sound engineering judgement and experience. The operability criteria with which the framework were populated are not specification-type requirements for a particular UAS, but were developed as guidelines which should be considered and implemented by the engineering domain, while developing the specification-type requirements and while developing and producing the UAS.

During the development of the criteria for the relevant sub-parts, sections and sub-sections of the framework, it was possible to evaluate the relevance, comprehensiveness and generic character of each sub-part, section and sub-section in respect of the development of UAS. As the populating process was not restricted to a particular type of UAS, the framework structure, as well as the operability criteria, had to be found sufficiently generic and comprehensive to allow their application to any type of UAS. This effort identified further framework refinements that were required and which were implemented. Subsequently, the framework structure and the populated framework were declared to be generic and comprehensive, and appropriate for application to any UAS.

In addition to the evaluation process, the levels at which the criteria were entered into the framework and the contents of the criteria were judged in respect of whether the criteria could be used from the framework for the development of UAS engineering and operability requirements, without further interpretation of the criteria. This step in the validation process also identified additional refinements that needed to be implemented before the criteria were declared to be appropriate for application in the UAS engineering domain.

From these results it was concluded that:

- the structure of the UAS operability framework had been validated; and
- the operability criteria, as presented in the populated framework included in Appendix C, Populated UAS Operability Framework Tables, are appropriate for application and use in the UAS engineering domain.

The final research question had therefore been addressed successfully as it was shown in this chapter that the UAS operability framework could be validated by populating it with appropriate, generic UAS operability criteria.

In the next chapter, the contributions that have been made by this study are described.

7. CONTRIBUTION

7.1. Introduction

This chapter describes the contribution made by this study to the body of UAS engineering knowledge. The contributions are separated into contributions in respect of the stated research questions, and general contributions.

7.2. Contributions in Respect of the Research Questions

Considering the research questions of this study, the following contributions had been made:

- **First research question**: By defining and implementing the term "UAS operability", as required by the first research question, the scope of issues that should be considered to ensure the safe and reliable functioning of the UAS is no longer limited to a review of regulatory airworthiness requirements only, but covers the UAS as a system, as well as its sub-systems. This term had not been used previously in this context and is therefore a new addition to UAS terminology.
- **Second research question**: Where other studies are concentrating on developing UAS airworthiness regulations, this study made a contribution by defining a relevant regulating domain in which UAS engineering criteria could be developed. This study then proceeded to generate an engineering tool, within the scope of the regulating domain, with which the UAS engineering domain can engineer safe and reliable UAS, whether regulated or not, and whether regulations exist or not. In addition, although the target application domain was not the regulating environment, but the UAS engineering domain, the UAS operability framework and criteria can potentially contribute to the development of the scope of UAS regulations.
- **Third research question (first contribution)**: As far as could be established from publicly available information, a generic and comprehensive framework for aircraft airworthiness, RLV flightworthiness or UAS operability criteria specifically developed for the engineering domain had not been published previously. By creating the UAS operability framework, and by populating it with relevant operability criteria, this study made a contribution by showing that it is

possible to develop this type of generic and comprehensive framework for complex systems such as UAS, and that such frameworks can be developed with appropriate relevance for the engineering domain.

- **Third research question (second contribution)**: A further contribution of the UAS operability framework is found in the fact that known criteria, as well as necessary new operability criteria associated with UAS, have been included in a single framework to cover UAS, their airborne sub-systems, their non-airborne sub-systems and their payloads.
- **Fourth research question**: Demonstrating the validity of the UAS operability framework was not limited to applying the framework to a few specific UAS. Instead, its generic and comprehensive characteristics were evaluated and validated by populating the framework with appropriate operability criteria. The operability criteria had to be sufficiently general in character to confirm that the framework could be applied to any type of UAS, and had to be appropriately detailed to allow their use in the engineering domain without further interpretation. This was achieved and the validation of the UAS operability framework made the final contribution by confirming that the UAS operability framework is a new, generic and comprehensive engineering tool that can be applied in the engineering domain for the development of safe and reliable UAS.

7.3. General Contributions

The process of developing the UAS operability framework and the operability criteria with which it is populated made several additional contributions, other than the contributions made in respect of the research questions.

These general contributions include the following:

- The study did not limit its scope to the traditional manned and unmanned aircraft airworthiness considerations, but introduced the proven knowledge and experience of the reusable launch vehicle domain, and further expanded the study to include systems engineering considerations for addressing the system-level operability issues of UAS.
- This study is the first to comprehensively address issues related to the safe and reliable functioning of a UAS from a wider perspective than just the aircraft and

the remote control station, in that it considers the operability of the UAS as a system of systems, of all the system's airborne sub-systems, of all its non-airborne sub-systems, as well as of its payloads.

- Through the structure of the UAS operability framework, as well as the operability criteria with which the framework was populated during its validation process, this study has created an engineering tool for the UAS engineering domain with which the process of developing a UAS can be enhanced by ensuring that the UAS does not only conform to client specifications, but can also function safely and reliably, whether the UAS is regulated or not.
- The UAS operability framework and its operability criteria provide for consistency in the development of UAS in the engineering domain, which is required to ensure eventual standardisation and interchangeability of products associated with UAS.
- The useability of the UAS operability framework and criteria is illustrated in Figure 7.1.

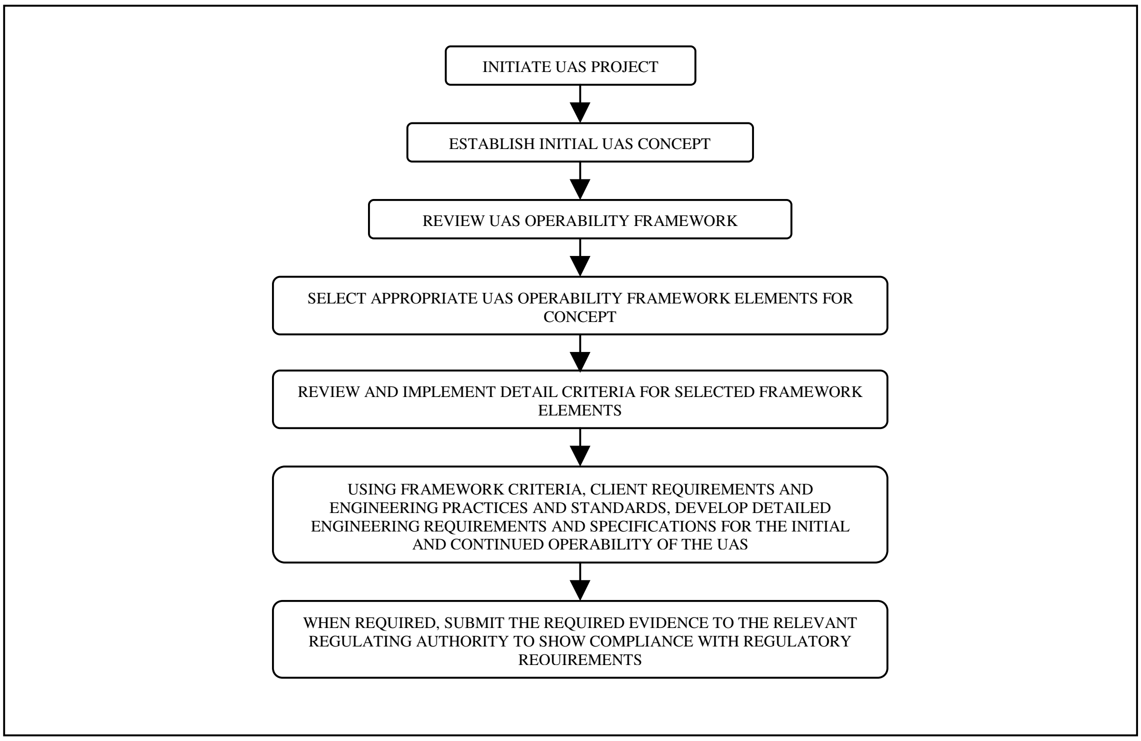

Figure 7.1 Useability of the UAS operability framework and criteria in the UAS engineering domain.

7.4. Summary

It is clear from reviewing the above contributions that the results of this study could affect both the UAS engineering domain and the UAS regulating environments. However, the most significant effect is expected to occur in the engineering domain where the UAS operability framework will be able to structure and guide the engineering development of UAS to ensure their safe and reliable functioning within the limits of an appropriate regulating domain, while conforming with client specifications.

The next chapter concludes this study with a review of the research effort.

8. CONCLUSION

8.1. Discussion and Reflection

This study focused on establishing a UAS operability framework to guide the engineering domain in developing UAS that would function safely and reliably in respect of the UAS as a system, and in respect of its airborne sub-systems, its non-airborne sub-systems and its payloads.

The original research for this thesis intended to develop continuous airworthiness criteria for UAS for both the engineering and regulating domains. However, the lack of UAS-unique initial airworthiness requirements required a change in the focus of the research to investigate the need for ensuring the safe and reliable functioning of the UAS as a system, rather than just the airworthiness of the aircraft, and to define an appropriate operability framework that would ensure that required safe and reliable functioning.

In addressing the UAS as a system with sub-systems, this study introduced the concept of 'UAS operability', where the operability of a UAS is defined to include:

- the reliable and safe functioning of the UAS as a system;
- the airworthiness (reliable and safe functioning) of the airborne sub-systems of the system, including the aircraft and any other airborne sub-systems required for the functioning of the UAS;
- the reliable and safe functioning of the non-airborne sub-systems of the system; and
- the reliable and safe functioning of payloads to be carried in or on the UAS aircraft.

An appropriate regulating domain was defined and the UAS operability framework was developed specifically for the engineering domain, while recognising the regulating limitations.

Finally, the validity of the operability framework was demonstrated by populating it with relevant operability criteria that can be utilised by the engineering domain to develop specific UAS operability requirements.

Reflecting on the research questions that were identified for this study, the following conclusions can be drawn:

- The concept of 'UAS operability' was shown to be feasible and was defined to include the UAS as a system, as well as its sub-systems.
- A regulatory domain was identified within which a UAS operability framework was developed for utilisation in the engineering domain.
- A generic UAS operability framework was developed, within the scope of typical aerospace regulatory frameworks, to address the operability criteria and requirements for UAS, their airborne sub-systems, their non-airborne sub-systems and their payloads.
- The operability framework was validated by populating it with appropriate, generic UAS operability criteria from which the engineering domain can develop relevant engineering requirements for the operability of a specific UAS, its airborne sub-systems, its non-airborne sub-systems and its payloads.

With each of the research questions satisfactorily addressed, the hypothesis for this study can be reviewed. Thus:

- A generic 'UAS Operability Framework' was established, within the scope of typical aerospace regulatory frameworks, to address the initial and continued operability of UAS, their airborne sub-systems, their non-airborne sub-systems and their payloads; and
- the 'UAS Operability Framework' was validated by populating it with appropriate criteria from which engineering requirements can be developed for the initial and continued operability of a UAS, including the system, its airborne sub-systems, its non-airborne sub-systems and its payloads.

The hypothesis for this study is therefore confirmed and the results of this research study are summarised graphically in Figure 8.1.

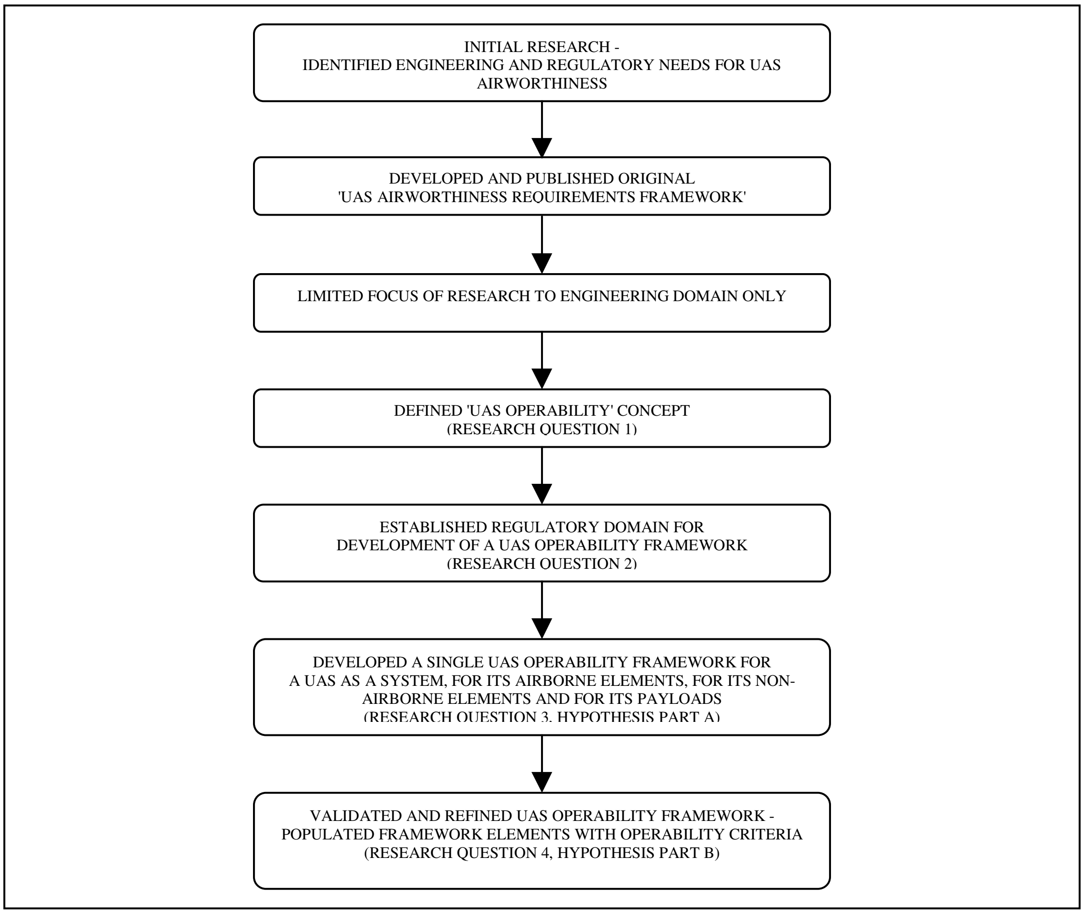

Figure 8.1 Summary of the results of this research study.

8.2. Recommendations

Although the UAS operability framework was developed to be generic and comprehensive, this research effort should be continued to address the following:

- The UAS operability framework and operability criteria should be applied to actual UAS development projects and their usefulness and applicability should be monitored and studied. The results of such studies should be incorporated into the framework to further improve and refine its structure and content.
- The UAS operability framework should be analysed and evaluated by regulating authorities for its potential adaptation and application in the regulatory domain. This is particularly relevant for inclusion of the non-traditional elements such as the UAS as a system, the non-airborne sub-systems and the payloads, in 'airworthiness' regulations.

- The scenario study that was conducted to define the regulatory domain for this study should be repeated regularly to incorporate new trends and technologies. The results of the scenario studies should be analysed and incorporated into the UAS operability framework to maintain the relevance of the framework and its content.
- In response to engineering, technology and regulatory developments and changes, the UAS operability framework, and in particular the operability criteria, should be reviewed and revised regularly to ensure that the framework and the criteria remain effective and state-of-the-art engineering tools in the development of UAS.
- The UAS operability framework and operability criteria should be considered as models for developing similar frameworks and criteria for other airspace users, including manned aircraft and spacecraft. The regular co-ordination of the operability frameworks for the different aerospace environments should also be considered to ensure compatibility and interchangeability of products not only within each environment, but also between different environments.

8.3. Closure

The primary objective of this research study was to establish a UAS operability framework to guide the engineering domain in developing UAS that would function safely and reliably in respect of the UAS as a system, its airborne sub-systems, its non-airborne sub-systems and its payloads. To achieve this objective, four research questions were defined and a hypothesis was formulated.

The research questions were each answered satisfactorily and the hypothesis was confirmed. It can therefore be declared that the objective of this research study was successfully achieved and with the UAS operability framework having been established and validated, this research study is herewith closed.

REFERENCES USED IN CHAPTERS

1 ICAO. Convention on International Civil Aviation. Document 7300/9. International Civil Aviation Organization. Montréal, Canada. 2006.

2 EASA. Advance-Notice of Proposed Amendment: Ref. A-NPA No. 16/2005. Policy for Unmanned Aerial Vehicle (UAV) Certification. Rulemaking Directorate, European Aviation Safety Agency. Köln, Germany. 2005.

3 USA FAA. Interim Operational Approval Guidance 08-01, Unmanned Aircraft Systems Operations in the U.S. National Airspace System. Unmanned Aircraft Program Office (AIR-160), Federal Aviation Administration. Washington, United States of America. 2008.

4 UK CAA. CAP 722 - Guidance for Unmanned Aerial Vehicle (UAV) Operations in UK Airspace. 2nd Edition. Directorate of Airspace Policy, UK Civil Aviation Authority. London, Great Britain. 2004.

5 Ingham, L.A. Considerations for a Roadmap for the Operation of Unmanned Aerial Vehicles (UAV) in South African Airspace. PhD Thesis. Stellenbosch University, South Africa. 2008.

6 Ingham, L.A., Jones, T. and Maneschijn, A. Certification of Unmanned Aerial Vehicles in South African Airspace. SAIME R&D Journal. Johannesburg, South Africa. 2006.

7 Ingham, L.A., Jones, T. and Maneschijn, A. Considerations for UAV Design and Operation in South African Airspace. The Aeronautical Journal. Volume 110, Number 1112. London, Great Britain. 2006.

8 Ingham, L.A., Jones, T., Maneschijn, A. Considerations for Flight Testing of UAVs in South African Airspace. The Aeronautical Journal. Volume 110, Number 1113. London, Great Britain. 2006.

9 Maneschijn, A., Jones, T., von Backström, T.W. and Ingham, L.A. A Proposed Reference Framework for Unmanned Aerial Vehicle and System Airworthiness Requirements. The Aeronautical Journal. Volume 111. Number 1120. London, Great Britain. 2007.

10 National (SA) UAS Policy Co-ordination Committee (Airworthiness Sub-committee) and Maneschijn, A. Interim Policy for Civil Unmanned Aircraft Systems in South Africa. SA CARCOM and SA Civil Aviation Authority. Johannesburg, South Africa. 2008.

11 Marais, W.J. (Col), Maneschijn, A. Military Aviation Authority: A South African Perspective. South African Air Force Presentation. EMAAG/IMAAC 2006, 16 – 18 October 2006. German Air Force Materiel Command. Cologne, Germany. 2006.

12 ICAO. ICAO Exploratory Meeting on Unmanned Aerial Vehicles (UAVs), Montréal, Canada, 23 - 24 May 2006. Summary of Discussions, ICAO-UAV WP/2. Montréal, Canada. 2006.

13 ICAO. AFI Planning and Implementation Regional Group Sixteenth Meeting - Progress Report on Unmanned Aerial Vehicle (UAV) Work. Doc. APIRG/16-IP/15, 13/11/07. Kigali, Rwanda. 2007.

14 ICAO. The Seventeenth Meeting of the APANPIRG ATM/AIS/SAR Sub-Group (ATM/AIS/SAR/SG/17). Doc. ATM/AIS/SAR/SG/17−WP/31, 2/7/07. Bangkok, Thailand. 2007.

15 Maneschijn, A. Developing a Feasible Engineering Policy to Ensure Continued Aviation Safety in the South African Air Force. M.Sc. (Aero.Eng.) Dissertation. University of the Witwatersrand. Johannesburg, South Africa. 2002.

16 Canadian Department of National Defence. UAV System Airworthiness Requirements (USARs) - Canadian Review and Input. http://www.uvscanada.org/documents/USAR_v3.0.pdf. Cited 12 July 2006.

17 NATO. Ratification of Draft STANAG 4671 on Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR). NATO Joint Capability Group on Unmanned Aerial Vehicles (JCGUAV). Doc. PFP(NNAG-JCGUAV)D(2007)0002, 9 May 2007. Brussels, Belgium. 2007.

18 JAA/EUROCONTROL. The Joint JAA/EUROCONTROL Initiative on UAVs. UAV TASK-FORCE Final Report. Joint Aviation Authorities. Amsterdam, Netherlands. 2004.

19 Haddon, D.R. and Whittaker, C.J. UK-CAA Policy for Light UAV Systems. Design & Production Standards Division, Civil Aviation Authority, Great Britain. 2004.

20 USA FAA. Guide to Commercial Reusable Launch Vehicle Operations and Maintenance Version 1.0, March 2005. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2005.

21 RTI International Center for Aerospace Technology. Reusable Launch Vehicles Operations and Maintenance Top-Down Analysis - Final Technical Report. RTI Report No. RTI/ 08087.002/Task 1.5-01F, 20 December 2002. Florida, United States of America. 2002.

22 USA FAA. Federal Aviation Regulations Title 14: Aeronautics and Space, Part 1 - Definitions and Abbreviations. Federal Aviation Administration. Washington, United States of America. 2009.

23 JAA. Joint Aviation Requirements JAR-1, Definitions and Abbreviations. Change 5, 15 July 1996. Joint Aviation Authorities Committee, Joint Aviation Authorities. Amsterdam, Netherlands. 1996.

24 EASA. CS-Definitions, Definitions and Abbreviations Used in Certification Specifications for Products, Parts and Appliances. ED Decision 2003/11/RM, 5 November 2003. European Aviation Safety Agency. Brussels, Belgium. 2003.

25 UK Ministry of Defence. JSP553, Military Airworthiness Regulations (2006) Edition 1 Change 5. http://en.wikipedia.org/wiki/Airworthy. Cited 3 September 2008.

26 Webster's Online Dictionary. "Flight-worthy: An aircraft, missile, or spacecraft is flight-worthy if it is ready and sufficiently sound in all respects to meet and endure the stresses and strains of flight. Source: European Union." http://www.websters-online-dictionary.org/fl/flight-worthy.html. Cited 11 November 2009.

27 Soanes, C., Spooner, A. and Hawker, S. Oxford Paperback Dictionary, Thesaurus and Wordpower Guide. 9th Edition. Oxford University Press. Oxford, Great Britain. 2001.

28 Collins Concise Dictionary. 21st Century Edition. HarperCollins Publishers. Glasgow, Great Britain. 2004.

29 Cambridge International Dictionary of English. Paperback Edition. Cambridge University Press. Cambridge, Great Britain. 1997.

30 Webster's Online Dictionary. http://www.websters-online-dictionary.org/definition/operable. Cited 11 November 2009.

31 Wikipedia Contributors. "Operability", Wikipedia. The Free Encyclopedia, Wikipedia. http://en.wikipedia.org/w/index.php?title=Operability&oldid=320876173. Cited 11 November 2009.

32 Cloete, F., Wissink, H. and de Coning, C. Improving Public Policy from Theory to Practice. Second Edition. Van Schaik Publishers. Pretoria, South Africa. 2006.

33 Baldwin, R. and Cave, M. Understanding Regulation - Theory, Strategy and Practice. Oxford University Press. Oxford, United Kingdom. 1999.

34 Von Backström, T.W. (Prof). E-mail correspondence to A. Maneschijn. 04:40PM, 19 July 2010. Department of Mechanical and Mechatronic Engineering, Stellenbosch University. Stellenbosch, South Africa. 2010.

35 OECD. Performance-Based Standards for the Road Sector. OECD International Transport Documentation (ITRD) Number E124118. OECD Publishing, Organisation for Economic Co-Operation and Development. Paris, France. 2005.

36 ICAO. ICAO Standards, Recommended Practices and Procedures - A Way Forward. Technical Commission Working Paper, 36th Session of the Assembly of ICAO. International Civil Aviation Organization. Montréal, Canada. 2007.

37 Fisher, B. Regulators Must Oversee Companies and People that Reflect the Entire Safety Spectrum. ICAO Journal, Volume 60, Number 4. International Civil Aviation Organization. Montréal, Canada. 2005.

38 External Advisory Committee on Smart Regulation. Smart Regulation: A Regulatory Strategy for Canada. Executive Summary. Report C200-4980270-4. Quebec, Canada. 2004.

39 Tatelman, T.B. Legal Developments in International Civil Aviation. Congressional Research Service (CRS) Report, Order Code RL33255. American Law Division, Congressional Research Service. Washington, United States of America. 2006.

40 ICAO. Annex 8 to the Convention on International Civil Aviation: Airworthiness of Aircraft. Ninth Edition. International Civil Aviation Organization. Montréal, Canada. 2001.

41 ICAO. Airworthiness Manual. First Edition. Doc. 9760. International Civil Aviation Organization. Montréal, Canada. 2001.

42 Dalamagkidis, K., Valavanis, K. P. and Piegl, L. A. Current Status and Future Perspectives for Unmanned Aircraft System Operations in the US. Journal of Intelligent and Robotic Systems (Online), Ref. DOI 10.1007/s10846-008-9213-x. Springer Science and Business Media BV, Netherlands. 2008.

43 USA FAA. Airworthiness Certification of Unmanned Aircraft Systems. Draft Order 8130.UAS. Federal Aviation Administration. Washington, United States of America. 2008.

44 Transport Canada. Unmanned Air Vehicle Working Group Final Report. Civil Aviation, Transport Canada. http://www.tc.gc.ca/CivilAviation/general/Recavi/uavworkinggroup.htm#12.1. Cited 6 May 2008.

45 CASA. Civil Aviation Act 1988. Consolidation, including amendments up to 21 August 2007. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2007.

46 CASA. Civil Aviation Safety Regulations 1998. Consolidation, including amendments up to 25 July 2007. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2007.

47 CASA. Civil Aviation Safety Regulations 1998 (Consolidation, including amendments up to 25 July 2007). Part 101, Unmanned Aircraft and Rocket Operations. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2007.

48 CASA. Civil Aviation Safety Regulations 1998 (Consolidation, including amendments up to 25 July 2007). Part 21, Certification and Airworthiness Requirements for Aircraft and Parts. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2007.

49 South African Government. Act No. 13 of 2009: Civil Aviation Act, 2009. South African Government Gazette. Volume 461, Number 32266, 27 May 2009. Cape Town, South Africa. 2009.

50 Beek, C.Z.A. Aviation Legislation in South Africa, Volume 2: Civil Aviation Regulations, 1997. Service Issue 20, December 2008. LexisNexis. Durban, South Africa. 2008.

51 van Duren, E.C.G.J. (Col). Developments in Military Aviation: A Military Aviation Authority Perspective. Host Nation Conference Warsaw, 28 June 2006. Warsaw, Poland. 2006.

52 Ministry of Defence. Regulation of the Airworthiness of Ministry of Defence Aircraft. JSP 318B. 4th Edition AL2. Defence Aviation Safety Board, MoD(DPA) Air Land Technology Group - ADRP. Bristol, Great Britain. 1999. (Note: In 2003, JSP 318B was re-issued as JSP 553 as part of the Military Aviation Regulation Document Set. The policy content of the 1st Edition of JSP 553 is identical to that of JSP 318B 4th Edition. http://www.ams.mod.uk/content/docs/avsaf/jsp553.htm. Cited 16 November 2007.)

53 Zwick, J. A Multinational Airworthiness Experience. NATO Airborne Early Warning & Control Force Command (NAEW&C FC) presentation. EMAAG/IMAAC 2006, 16 – 18 October 2006. German Air Force Materiel Command. Cologne, Germany. 2006.

54 Military Flight Safety Inspectorate (FLYGI). Rules of Military Aviation (RML). Issue 2, 26 September 2000. Swedish Armed Forces. Sweden. 2000.

55 Chief of the Defence Staff. Technical Airworthiness Manual (TAM). Doc. C-05-005-001/AG-001 Change 4, 31 January 2006. Canadian Department of National Defence. Ontario, Canada. 2006.

56 Chief of the Defence Staff. Airworthiness Design Standards Manual (ADSM). C-05-005-001/AG-002. August 2006. Canadian Department of National Defence. Ontario, Canada. 2006.

57 Air Marshal. ADF Airworthiness Manual. Australian Air Publication 7001.048(AM1), 5 April 2001. Airworthiness Authority, Australian Defence Force. Australia. 2001.

58 Kirschner, L., Longeville, O., Harrison, S. and Bravarone, R. Investigation into Harmonisation of Military Aviation Regulation across the EU – What Outcome should Industry Aim for? Document No. ECATA MTP2 130 Final Report R1v2, 23rd April 2007. ECATA MTP2 Team, European Consortium for Advanced Training in Aerospace (ECATA). Toulouse, France. 2007.

59 Rehn, T. Swedish Armed Forces' UAV System Vision for Operation in Non-Segregated Airspace. Issue 2, Enclosure 1 to HKV 29 Nov 2004, 29 November 2004. Doc. Ref. 02 810:77056. Swedish Armed Forces Headquarters, Swedish Armed Forces. Sweden. 2004.

60 Chief of Staff. Aviation Unmanned Aerial Vehicle Flight Regulations. Army Regulation 95–23, 14 May 2004. Department of the Army, United States Army. Washington, United States of America. 2004.

61 Joint Airworthiness Committee - UAV System Sub Committee. Design and Airworthiness Requirements for Service Aircraft - UAV Systems. Defence Standard 00-970 Part 9. Issue 4, 27 January 2006. Defence Procurement Agency, Ministry of Defence. Bristol, Great Britain. 2006.

62 USAR Working Group (2004). UAV Systems Airworthiness Requirements (USAR). Version 3.0, 20 January 2005. UAV Flight Test Team Manager, Délégation Générale des Armements (DGA). Istres, France. 2005.

63 EASA. CS-23, Certification Specifications for Normal, Utility, Aerobatic, and Commuter Category Aeroplanes. ED Decision 2003/14/RM, 14 November 2003. European Aviation Safety Agency. Brussels, Belgium. 2003.

64 Milde, M. Legal Status of Military Aircraft: ICAO Safety Standards and the Military Aircraft. SA Air Force Executive Safety Management Seminar, 30 October 2007. Pretoria, South Africa. 2007.

65 EUROCONTROL. The Single European Sky. http://www.eurocontrol.int/ses/public/subsite_homepage/homepage.html. Cited 8 May 2008.

66 EUROCONTROL. Civil-Military Co-Operation. http://www.eurocontrol.int/corporate/public/standard_page/cb_civilmilitary.html. Cited 8 May 2008.

67 Committee F38 on Unmanned Aircraft Systems. The American Society for Testing and Materials (ASTM). http://www.astm.org/COMMIT/COMMITTEE/F38.htm. Cited 27 October 2010.

68 EUROCAE. WG-73 - Unmanned Aircraft Systems (UAS). The European Organisation for Civil Aviation Equipment. http://www.eurocae.net/workinggroups.html. Cited 27 October 2010.

69 Baumann, A. and Lintener, M. Proposal for the Integration of UAS into Non-segregated Airspace. The Innovative Operational UAS Integration (INOUI) Consortium. EC - INOUI Booklet.pdf. 14 December 2009. European Commission Contract TREN/07/FP6AE/S07.69061/037191. Langen, Germany. 2009.

70 Joulia, A. D3.2: UAS Certification. Final Report. Version 1.1. INOUI_WP3.2_ONE_D3.2_PU_v1.1.pdf. 26 May 2009. European Commission Contract TREN/07/FP6AE/S07.69061/037191. Langen, Germany. 2009.

71 RTCA, Inc. Committee SC-203. Unmanned Aircraft Systems. http://www.rtca.org/comm/Committee.cfm?id=45. Cited 2 June 2006 and 27 October 2010.

72 IHS. RTCA Addresses Unmanned Aircraft Systems - RTCA DO-304. http://aero-defense.ihs.com/news/rtca-uas-guidance.htm. Cited 27 October 2010.

73 DeFlorio, F. Airworthiness for UAVs - A Discussion Paper, 15 May 2000. http://www.uvs-info.com/UAS_Publications/5w_Ref-Doc_RA.php?tri=RA_Org. Cited 30 September 2007.

74 Neild, I. and Pearson, I. 2005 BT Technology Timeline. British Telecom. http://www.btplc.com/Innovation/News/timeline/TechnologyTimeline.pdf. Cited 4 September 2007.

75 Barrie, A. Science-Fiction Writers Help Government Prepare for Attacks of the Future. Fox News, USA. www.foxnews.com. 2 May 2008. Cited in UVS News Flash, Issue 2008/09, 10 May 2008. Blyenburgh & Co. Paris, France. 2008.

76 Ilbury, C. and Sunter, C. Games Foxes Play - Planning for Extraordinary Times. First Edition. Human & Rousseau, Tafelberg Publishers. Cape Town, South Africa. 2005.

77 Global Business Environment. Scenarios: An Explorer’s Guide. Exploring the Future. Shell Visual Media Services, Shell International. London, Great Britain. 2003.

78 Grundy, P. Shell Energy Scenarios to 2050. Shell International BV. The Hague, Netherlands. 2008.

79 SRI Consulting Business Intelligence (SRIC-BI). Disruptive Civil Technologies - Six Technologies with Potential Impacts on US Interests out to 2025. CR 2008-07, April 2008. National Intelligence Council, Director of National Intelligence. United States of America. 2008.

80 UVS International. Non-Military Applications of UAS-WRC. UVS International document supplied by EUROCONTROL to the World Radio Conference, Geneva, Switzerland, 2007. UVS News Flash & Notifications e-mail dated 4 November 2007. Blyenburgh & Co. Paris, France. 2007.

81 DIY Drones. Amateur UAV's, Contests, Resources and more. http://diydrones.com/. Cited 24 June 2008.

82 Pardesi, M.S. Unmanned Aerial Vehicles/Unmanned Combat Aerial Vehicles - Likely Missions and Challenges for the Policy-Relevant Future. Air and Space

Power Journal, Fall 2005. AFRP-01, Volume XIX, Number 3. United States Air Force. United States of America. 2005.

83 Turner, A. How Europe Aims to Clean Up the Skies. Flight International 27 May 2008. http://www.flightglobal.com/articles. Cited 28 May 08.

84 USA FAA. Concept of Operations for the Next Generation Air Transportation System. Version 2.0, 13 June 2007. Federal Aviation Administration. Washington, United States of America. 2007.

85 Rotor News. Piasecki Aircraft-Carnegie Mellon Demonstrate Autonomous Helicopter Collision Avoidance & Landing Zone Selection System. Helicopter Association International. http://new.rotor.com/Publications/RotorNewssupregsup/tabid/177/newsid375/71130/Default.aspx. Cited 21 July 2010.

86 van der Merwe, A.J. Towards a Reusable Process Model Structure for Higher Education Institutions. PhD Thesis. University of South Africa. Pretoria, South Africa. 2005.

87 Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering. Systems Engineering Guide for Systems of Systems, Version 1.0. Washington DC, United States of America. 2008.

88 NASA. NASA Procedural Requirements: Systems Engineering Processes and Requirements. NPR 7123.1A, 26 March 2007. Office of the Chief Engineer, NASA. United States of America. 2007.

BIBLIOGRAPHY

American Institute of Aeronautics and Astronautics. "Guide to the Identification of Safety-Critical Hardware Items for Reusable Launch Vehicle (RLV) Developers." 1 May 2005. Virginia, United States of America, 2005.

ASTM International. ASTM Standard F 2584-06 Standard Practice for Maintenance and Development of Maintenance Manuals for Light Unmanned Aircraft System (UAS). Pennsylvania, United States of America. 2006.

ASTM International. Technical Committee F38 on Unmanned Aircraft Systems. http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/COMMITTEE/ F38.htm?L+mystore+lraa5749. Cited 23 March 2006.

Atkinson, C. et al. Framework for the Application of Systems Engineering in the Commercial Aircraft Domain. Draft Version 1.2a, 28 July 2000. Joint Commercial Aircraft Working Group, International Council on Systems Engineering (INCOSE). San Diego, United States of America. 2000.

Australian Defence Force. Australian Air Publication 7001.048(AM1). ADF Airworthiness Manual. 5 April 2001. ACPA-ADF ADF Airworthiness Authority. Australia. 2001.

Baldwin, R. and Cave, M. Understanding Regulation - Theory, Strategy and Practice. Oxford University Press. Oxford, United Kingdom. 1999.

Barrie, A. Science-Fiction Writers Help Government Prepare for Attacks of the Future. Fox News, USA. www.foxnews.com. 2 May 2008. Cited in UVS News Flash, Issue 2008/09, 10 May 2008. Blyenburgh & Co. Paris. 2008.

Baumann, A. and Lintener, M. Proposal for the Integration of UAS into Non-segregated Airspace. The Innovative Operational UAS Integration (INOUI) Consortium. EC - INOUI Booklet.pdf. 14 December 2009. European Commission Contract TREN/07/FP6AE/S07.69061/037191. Langen, Germany. 2009.

Beek, C.Z.A. Aviation Legislation in South Africa, Volume 1: Aviation Act No. 74 of 1962. Service Issue 38, October 2008. LexisNexis. Durban, South Africa. 2008.

Beek, C.Z.A. Aviation Legislation in South Africa, Volume 2: Civil Aviation Regulations, 1997. Service Issue 20, December 2008. LexisNexis. Durban, South Africa. 2008.

Biteus, J., Cedersund, G., Frisk, E., Krusander, M. and Nielson, L. Improving Airplane Safety by Incorporating Diagnosis into Existing Safety Practice. 23 November 2004. Department of Electrical Engineering, Linkoping. Sweden. 2004.

Cambridge International Dictionary of English. Paperback Edition. Cambridge University Press. Cambridge, Great Britain. 1997.

Canadian Department of National Defence. UAV System Airworthiness Requirements (USARs) - Canadian Review and Input. http://www.uvscanada.org/documents/USAR_v3.0.pdf. Cited 12 July 2006.

Canfora, G. & Cimitile, A. Software Maintenance. 29 November 2000. Faculty of Engineering, University of Sannio. Benevento, Italy. 2000.

CASA. Civil Aviation Act 1988. Civil Aviation Safety Authority. Canberra, Australia. 2007.

CASA. Civil Aviation Safety Regulations 1998 (Consolidation, including amendments up to 25 July 2007). Part 101, Unmanned Aircraft and Rocket Operations. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2007.

CASA. Civil Aviation Safety Regulations 1998 (Consolidation, including amendments up to 25 July 2007). Part 21, Certification and Airworthiness Requirements for Aircraft and Parts. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2007.

CASA. Civil Aviation Safety Regulations 1998. Consolidation, including amendments up to 25 July 2007. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2007.

CASA. Civil Aviation Safety Regulations Part 101, Unmanned Aircraft and Rocket Operations. 1st Edition. July 2002. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2002.

CASA. UAV Design Standards - Rotorcraft (Draft). Version 2.2, 26 May 2000. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2000.

CASA. Unmanned Aircraft and Rockets: Unmanned Aerial Vehicle (UAV) Operations, Design Specification, Maintenance and Training of Human Resources. AC 101-1(0), July 2002. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2002.

Certification Directorate. Continuing Airworthiness of Type Design Procedure (CAP). Doc # C.P006-01. 10 March 2008. European Aviation Safety Agency. Belgium. 2008.

Chief of Staff. Aviation Unmanned Aerial Vehicle Flight Regulations. Army Regulation 95–23, 14 May 2004. Department of the Army, United States Army. Washington, United States of America. 2004.

Chief of the Defence Staff. Airworthiness Design Standards Manual (ADSM). C-05-005-001/AG-002. August 2006. Canadian Department of National Defence. Ontario, Canada. 2006.

Chief of the Defence Staff. Technical Airworthiness Manual (TAM). Doc. C-05-005-001/AG-001 Change 4, 31 January 2006. Canadian Department of National Defence. Ontario, Canada. 2006.

Cloete, F., Wissink, H. and de Coning, C. Improving Public Policy from Theory to Practice. Second Edition. Van Schaik Publishers. Pretoria, South Africa. 2006.

Clothier, R.A. and Walker, R.A. Determination and Evaluation of UAV Safety Objectives. Proceedings of the 21st International Unmanned Air Vehicle Systems Conference. Bristol, Great Britain. 2006. Pages 18.1-18.16.

Collins Concise Dictionary. 21st Century Edition. HarperCollins Publishers. Glasgow, Great Britain. 2004.

Committee F38 on Unmanned Aircraft Systems. The American Society for Testing and Materials (ASTM). http://www.astm.org/COMMIT/COMMITTEE/F38.htm. Cited 27 October 2010.

Cox, T.H.(NASA), Nagy, C.J.(NASA), Skoog, M.A.(NASA) and Somers, I.A.(CSM, Inc). Civil UAV Capability Assessment. Draft Version. December 2004. Prepared for NASA Aeronautics Research Mission Directorate and NASA Science Mission Directorate. United States of America. 2004.

Dahmann, J., Lane, J.A., Rebovich Jr, G., Baldwin, K.J. A Model of Systems Engineering in a System of Systems Context. Paper 215, 6th Annual Conference on Systems Engineering Research. California, United States of America. 2008.

Dalamagkidis, K., Valavanis, K. P. and Piegl, L. A. Current Status and Future Perspectives for Unmanned Aircraft System Operations in the US. Journal of Intelligent and Robotic Systems (Online), Ref. DOI 10.1007/s10846-008-9213-x. Springer Science and Business Media BV, Netherlands. 2008.

Defense Acquisition University. Defense Acquisition Guidebook, 19 February 2010. Defense Acquisition University. https://dag.dau.mil. Fort Belvoir, United States of America. Cited 23 March 2010.

Defense Acquisition University. Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System Wallchart. Version 5.3.4, June 2009. OP-CL Publications/Distribution, Defense Acquisition University. http://acc.dau.mil/IFC/index.htm. Fort Belvoir, United States of America. 2009.

DeFlorio, F. Airworthiness for UAVs - A Discussion Paper, 15 May 2000. http://www.uvs-info.com/UAS_Publications/5w_Ref-Doc_RA.php?tri=RA_Org. Cited 30 September 2007.

DeGarmo, MT. Issues Concerning Integration of Unmanned Aerial Vehicles in Civil Airspace. Report MP 04W0000323, November 2004. Center for Advanced Aviation System Development, The MITRE Corporation. Virginia, United States of America. 2004.

Dixon, S.R. & Wickens, C.D. Reliability in Automated Aids for Unmanned Aerial Vehicle Flight Control: Evaluating a Model of Automation Dependence in High Workload. March 2004. Technical Report, Aviation Human Factors Division, Institute of Aviation, University of Illinois at Urbana-Champaign, Savoy. Illinois, United States of America. 2004.

DIY Drones. Amateur UAV's, Contests, Resources and more. http://diydrones.com/. Cited 24 June 2008.

EASA. Advance-Notice of Proposed Amendment: Ref. A-NPA No. 16/2005. Policy for Unmanned Aerial Vehicle (UAV) Certification. Rulemaking Directorate, European Aviation Safety Agency. Köln, Germany. 2005.

EASA. CS-23, Certification Specifications for Normal, Utility, Aerobatic, and Commuter Category Aeroplanes. ED Decision 2003/14/RM, 14 November 2003. European Aviation Safety Agency. Brussels, Belgium. 2003.

EASA. CS-29, Certification Specifications for Large Rotorcraft. ED Decision 2003/16/RM, 14 November 2003. European Aviation Safety Agency. Brussels, Belgium. 2003.

EASA. CS-Definitions, Definitions and Abbreviations Used in Certification Specifications for Products, Parts and Appliances. ED Decision 2003/11/RM, 5 November 2003. European Aviation Safety Agency. Brussels, Belgium. 2003.

Erdil, K., Finn, E., Keating, K., Meattle, J., Park, S. & Yoon, D. Software Maintenance as Part of the Software Life Cycle. 16 December 2003. Department of Computer Sciences, Tufts University. Massachusetts, United States of America. 2003.

EUROCAE. WG-73 - Unmanned Aircraft Systems (UAS). The European Organisation for Civil Aviation Equipment. http://www.eurocae.net/workinggroups.html. Cited 27 October 2010.

EUROCONTROL. Civil-Military Co-Operation. http://www.eurocontrol.int/ corporate/public/standard_page/cb_civilmilitary.html. Cited 8 May 2008.

EUROCONTROL. The Single European Sky. http://www.eurocontrol.int/ses/public/ subsite_homepage/homepage.html. Cited 8 May 2008.

European Military Aviation Authorities Group (EMAAG). EMAAG Presentation. (EMAAG[1].ppt). Military Aviation Authority, Ministary of Defense. Netherlands. 2004.

Evans, A.R. The Hazards of Unmanned Air Vehicle Integration into Unsegregated Airspace. M.Sc. (Safety Critical Systems Engineering) Research Report. September 2006. University of York. York, Great Britain. 2006.

Eveleens, R.L.C. Integrated Modular Avionics: Development Guidance and Certification Considerations. 5 June 2008. National Aerospace Laboratory NLR. Amsterdam, Netherlands. 2008.

External Advisory Committee on Smart Regulation. Smart Regulation: A Regulatory Strategy for Canada. Executive Summary. Report C200-4980270-4. Quebec, Canada. 2004.

Ferrell, T.K. and Ferrell, U.D. RTCA DO-178B/EUROCAE ED-12B. Chapter 27, The Avionics Handbook. Senior Editor: Spitzer, C.R.. CRC Press LLC. Massachusetts, United States of America. 2001

Fisher, B. Regulators Must Oversee Companies and People that Reflect the Entire Safety Spectrum. ICAO Journal, Volume 60, Number 4. International Civil Aviation Organization. Montréal, Canada. 2005.

Fudge, M., Stagliano, T. & Tsiao, S. Non-Traditional Flight Safety Systems & Integrated Vehicle Health Management Systems. Descriptions of Proposed & Existing Systems and Enabling Technologies & Verification Methods. 26 August 2003. Final Report. ITT Industries: Advanced Engineering & Science Division. Virginia, United States of America. 2003.

Gavales, J. & Hamilton, B.A. The 2003 Systems Engineering Benchmarking Study: A Summary for the AIAA. 10 November 2005. NASA Lyndon B. Johnson Space Center. Houston, Texas. 2005.

Global Business Environment. Scenarios: An Explorer's Guide. Exploring the Future. Shell Visual Media Services, Shell International. London, Great Britain. 2003.

Grundy, P. Shell Energy Scenarios to 2050. Shell International BV. The Hague, Netherlands. 2008.

Haddon, D.R. and Whittaker, C.J. Aircraft Airworthiness Certification Standards for Civil UAVs. The Aeronautical Journal. Volume 107, Number 1068. pp 79 - 86. London, Great Britain. February 2003.

Haddon, D.R. and Whittaker, C.J. UK-CAA Policy for Light UAV Systems. Design & Production Standards Division, Civil Aviation Authority, Great Britain. 2004.

Hardy, T.L. Integrating Launch Vehicle Safety and Reliability Analyses. Proceedings of the 23rd International System Safety Conference, August 22-26, 2005. United States of America. 2005.

Headquaters, Department of the Army. Technical Manual: Reliability/Availability of Electrical & Mechanical Systems for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities. 14 March 2003. Technical Manual. Washington DC, United States of America, 2003.

Headquaters, Department of the Army. Technical Manual: Reliability-Centered Maintenance (RCM) for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities. 3 May 2003. Technical Manual. Washington DC, United States of America. 2003.

ICAO. AFI Planning and Implementation Regional Group Sixteenth Meeting - Progress Report on Unmanned Aerial Vehicle (UAV) Work. Doc. APIRG/16-IP/15, 13/11/07. Kigali, Rwanda. November 2007.

ICAO. Airworthiness Manual. First Edition. Doc. 9760. International Civil Aviation Organization. Montréal, Canada. 2001.

ICAO. Annex 8 to the Convention on International Civil Aviation: Airworthiness of Aircraft. Ninth Edition. International Civil Aviation Organization. Montréal, Canada. 2001.

ICAO. Convention on International Civil Aviation. Document 7300/9. International Civil Aviation Organization. Montréal, Canada. 2006.

ICAO. ICAO Exploratory Meeting on Unmanned Aerial Vehicles (UAVs), Montréal, Canada, 23 - 24 May 2006. Summary of Discussions, ICAO-UAV WP/2. Montréal, Canada. 2006.

ICAO. ICAO Standards, Recommended Practices and Procedures - A Way Forward. Technical Commission Working Paper, 36th Session of the Assembly of ICAO. International Civil Aviation Organization. Montréal, Canada. 2007.

ICAO. Model Aviation Regulatory Document: Law, Regulations, and Implementing Standards and Training. Fourth Meeting of Directors of Civil Aviation of the Central Caribbean. May 2000.

ICAO. The Seventeenth Meeting of the APANPIRG ATM/AIS/SAR Sub-Group (ATM/AIS/SAR/SG/17). Doc. ATM/AIS/SAR/SG/17−WP/31, 2/7/07. Bangkok, Thailand. 2007.

ICAO. Working Paper 13 of The Sixteenth Meeting of the ICAO APANPIRG ATM/AIS/SAR Sub-Group, Bangkok, Thailand, 26 – 30 June 2006. Agenda Item 4, ATM/AIS/SAR/SG/16−WP/13. Bangkok. June 2006.

IHS. RTCA Addresses Unmanned Aircraft Systems - RTCA DO-304. http://aero-defense.ihs.com/news/rtca-uas-guidance.htm. Cited 27 October 2010.

Ilbury, C. and Sunter, C. Games Foxes Play - Planning for Extraordinary Times. First Edition. Human & Rousseau, Tafelberg Publishers. Cape Town, South Africa. 2005.

INCOSE. Systems Engineering Handbook: A "How To" Guide. Version 2.0. International Council on Systems Engineering. California, United States of America. 2000.

Ingham, L.A. Considerations for a Roadmap for the Operation of Unmanned Aerial Vehicles (UAV) in South African Airspace. PhD Thesis. Stellenbosch University, South Africa. 2008.

Ingham, L.A., Jones, T. and Maneschijn, A. Certification of Unmanned Aerial Vehicles in South African Airspace. SAIME R&D Journal. Johannesburg, South Africa. 2006.

Ingham, L.A., Jones, T. and Maneschijn, A. Considerations for UAV Design and Operation in South African Airspace. The Aeronautical Journal. Volume 110, Number 1112. London, Great Britain. 2006.

Ingham, L.A., Jones, T., Maneschijn, A. Considerations for Flight Testing of UAVs in South African Airspace. The Aeronautical Journal. Volume 110, Number 1113. London, Great Britain. 2006.

ISO Secretariat. ISO/IEC JTC 1/SC 7 N xxxx. Life Cycle Management - System Life Cycle Processes. ISO/IEC JTC 1/SC 7/WG 7 N0316. 21 January 2000. ISO Secretariat. Canada. 2000.

JAA. Joint Aviation Requirements JAR-1, Definitions and Abbreviations. Change 5, 15 July 1996. Joint Aviation Authorities Committee, Joint Aviation Authorities. Amsterdam, Netherlands. 1996.

JAA/EUROCONTROL. The Joint JAA/EUROCONTROL Initiative on UAVs. UAV TASK-FORCE Final Report. Joint Aviation Authorities. Amsterdam, Netherlands. 2004.

Johnson, L.A. DO-178B, Software Considerations in Airborne Systems and Equipment Certification. Flight Systems, Boeing Commercial Airplane Group. Washington DC, United States of America. 1998.

Joint Airworthiness Committee - UAV System Sub Committee. Design and Airworthiness Requirements for Service Aircraft - UAV Systems. Defence Standard 00-970 Part 9. Issue 4, 27 January 2006. Defence Procurement Agency, Ministry of Defence. Bristol, Great Britain. 2006.

Joulia, A. D3.2: UAS Certification. Final Report. Version 1.1. INOUI_WP3.2_ONE_D3.2_PU_v1.1.pdf. 26 May 2009. European Commission Contract TREN/07/FP6AE/S07.69061/037191. Langen, Germany. 2009.

Kennedy, J.J. Jr., Esq. Is International and Municipal Law Congruous to the Development of Fledgling Commercial Space Businesses? 25 April 2006. www.newmexicospacealliance.org/pdffiles/legalbrief1.pdf. Cited 25 May 2006.

Kirschner, L., Longeville, O., Harrison, S. and Bravarone, R. Investigation into Harmonisation of Military Aviation Regulation across the EU – What Outcome should Industry Aim for? Document No. ECATA MTP2 130 Final Report R1v2, 23rd April 2007. ECATA MTP2 Team, European Consortium for Advanced Training in Aerospace (ECATA). Toulouse, France. 2007.

Klimack, B., Kwinnm M.J. & Mark, M. Lead-the-Fleet: Transitioning Army Aviation Maintenance from a Time Based System to a Usage Based System. June 2004. Technical Report. United States Military Academy, West Point. New York, United States of America. 2004.

LtCol Apon, J-P. Update on the Developments in the Field of Unmanned Aerial Systems – EMAAG 2008. 23 October 2008. Military Aviation Authority, Ministary of Defense. Netherlands. 2008.

Maneschijn, A. Developing a Feasible Engineering Policy to Ensure Continued Aviation Safety in the South African Air Force. M.Sc. (Aero.Eng.) Dissertation. University of the Witwatersrand. Johannesburg, South Africa. 2002.

Maneschijn, A., Jones, T., von Backström, T.W. and Ingham, L.A. A Proposed Reference Framework for Unmanned Aerial Vehicle and System Airworthiness Requirements. The Aeronautical Journal. Volume 111. Number 1120. London, Great Britain. 2007.

Marais, W.J. (Col), Maneschijn, A. Military Aviation Authority: A South African Perspective: October 2006. South African Air Force Presentation Paper. 2006 International Military Aviation Authorities Conference. Cologne, Germany. 2006.

Martin, J.N. Processes for Engineering a System. Chapter 24, The Avionics Handbook. Senior Editor: Spitzer, C.R.. CRC Press LLC. Massachusetts, United States of America. 2001

McMillan, J. Automated Assistance to Administrative Decision-making: Launch of the Better Practice Guide. 23 April 2007. Text of an address by Professor John McMillan to a seminar of the Institute of Public Administration of Australia. Canberra, Australia. 2007.

Milde, M. Legal Status of Military Aircraft: ICAO Safety Standards and the Military Aircraft. SA Air Force Executive Safety Management Seminar, 30 October 2007. Pretoria, South Africa. 2007.

Military Flight Safety Inspectorate (FLYGI). Rules of Military Aviation (RML). Issue 2, 26 September 2000. Swedish Armed Forces. Sweden. 2000.

Mizukami, M. Computer-Aided Systems Engineering for Flight Research Projects Using a Workgroup Database. December 2004. NASA Dryden Flight Research Center. California, United States of America. 2004.

Munns, T.E., Beard, R.E., Culp, A.M., Murphy, D.A. & Kent, R.M. Analysis of Regulatory Guidance for Health Monitoring. December 2000. National Aeronautics and Space Administration, Langley Research Center, Virginia and ARINC, Inc., Maryland. United States of America. 2000.

NASA ERAST Certification Alliance Certification Project. High Altitude Long Endurance Unmanned Aerial Vehicles Certification and Regulatory Roadmap. Version 1.3. 26 August 2002. United States of America. 2002.

NASA. NASA Procedural Requirements: Systems Engineering Processes and Requirements. NPR 7123.1A, 26 March 2007. Office of the Chief Engineer, NASA. United States of America. 2007.

National (SA) UAS Policy Co-ordination Committee (Airworthiness Sub-committee) and Maneschijn, A. Interim Policy for Civil Unmanned Aircraft Systems in South Africa. SA CARCOM and SA Civil Aviation Authority. Johannesburg, South Africa. 2008.

National Aeronautics and Space Administration. NASA Software Safety Guidebook. 31 March 2004. NASA Technical Standard. Director, Safety and Risk Management Division (Code QS). National Aeronautics and Space Administration Headquarters. Washington DC, United States of America. 2004.

National Aeronautics and Space Administration. NASA Systems Engineering Handbook. Revision1. December 2007. NASA Headquaters. Washington DC, United States of America. 2007.

National Aeronautics and Space Administration. Planning, Developing and Managing an Effective Reliability and Maintainability (R&M) Program. December 1998. NASA Technical Standard. Director, Safety and Risk Management Division (Code QS). National Aeronautics and Space Administration Headquarters. Washington DC, United States of America. 1998.

National Archives and Records Administration. Electronic Code of Federal Regulations (e-CFR), Title 14 - Aeronautics and Space, Chapter 1. United States of America. Federal Aviation Administration. http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?&c=ecfr&tpl=/ecfrbrowse/Title14/14tab_02.tpl. Cited 3 October 2009.

NATO. Ratification of Draft STANAG 4671 on Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR). NATO Joint Capability Group on Unmanned Aerial Vehicles (JCGUAV). Doc. PFP(NNAG-JCGUAV)D(2007)0002, 9 May 2007. Brussels, Belgium. 2007.

Neild, I. and Pearson, I. 2005 BT Technology Timeline. British Telecom. http://www.btplc.com/Innovation/News/timeline/TechnologyTimeline.pdf. Cited 4 September 2007.

Nowlan, F.S. and Heap, H.F. Reliability-Centred Maintenance. Report No. A066-579. United Airlines. San Francisco, United States of America. 1978.

OECD. Performance-Based Standards for the Road Sector. OECD International Transport Documentation (ITRD) Number E124118. OECD Publishing, Organisation for Economic Co-Operation and Development. Paris, France. 2005.

Office for Official Publications of the European Communities. Report of the Group of Personalities. European Aeronautics: A Vision for 2020. European Commission. Luxembourg. 2001.

Office of Secretary of Defense. Designing and Assessing Supportability by DOD Weapons Systems: A Guide to Increased Reliability and Reduced Logistics Footprint. Memorandum for the The Acquisition Community. 24 October 2003. Washington DC, United States of America. 2003.

Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering. Systems and Software Engineering: Defense Acquisition Program Support (DAPS) Methodology Version 2.0 Washington DC, United States of America. 2009.

Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering. Systems Engineering Guide for Systems of Systems, Version 1.0. Washington DC, United States of America. 2008.

Parametric Technology Corporation (PTC). White Paper: Total Lifecycle Systems Management (TLCSM). Overcoming the Achilles Heel in Today's Aerospace and Defense (A&D) Weapon Systems Development. Report 4172-A&D-WP-0109. Massachusetts, United States of America. January 2009.

Pardesi, M.S. Unmanned Aerial Vehicles/Unmanned Combat Aerial Vehicles - Likely Missions and Challenges for the Policy-Relevant Future. Air and Space Power Journal, Fall 2005. AFRP-01, Volume XIX, Number 3. United States Air Force. United States of America. 2005.

Pennell, LW and Knight FL. Systems Engineering. Draft Military Standard Mil-Std-499C, 15 April 2005. The Aerospace Corporation, Report No. TOR-2005(8583)-3. California, USA. http://www.everyspec.com/MIL-STD/MIL-STD+(0300+-+0499)/MIL-STD-499C_(DRAFT)_3775/. California, United States of America. Cited 23 March 2010.

Rehn, T. Swedish Armed Forces' UAV System Vision for Operation in Non-Segregated Airspace. Issue 2, Enclosure 1 to HKV 29 Nov 2004, 29 November 2004.

Doc. Ref. 02 810:77056. Swedish Armed Forces Headquarters, Swedish Armed Forces. Sweden. 2004.

Robinson, R., Li, M., Lintelman, S., Sampigethaya, K., Poovendran, R., Von Oheimb, D., Buber, J-U. & Cuellar, J. Electronic Distribution of Airplane Software and the Impact of Information Security on Airplane Safety. Proceedings of the 26th International Conference on Computer Safety, Reliability and Security. Springer LNCS. 2007.

Rotor News. Piasecki Aircraft-Carnegie Mellon Demonstrate Autonomous Helicopter Collision Avoidance & Landing Zone Selection System. Helicopter Association International. http://new.rotor.com/Publications/RotorNewssupregsup/tabid/177/newsid375/71130/Default.aspx. Cited 21 July 2010.

RTCA, Inc. Committee SC-203. Unmanned Aircraft Systems. http://www.rtca.org/comm/Committee.cfm?id=45. Cited 2 June 2006 and 27 October 2010.

RTI International Center for Aerospace Technology. Reusable Launch Vehicle Operations and Maintenance Guideline Inputs and Technical Evaluation Report: Approval - Volume 5, Final Report. RTI Report No. RTI/ 08087/007/3.2-Vol5F, 18 November 2004. Florida, United States of America. 2004.

RTI International Center for Aerospace Technology. Reusable Launch Vehicle Operations and Maintenance Guideline Inputs and Technical Evaluation Report: Maintenance - Volume 3, Final Report. RTI Report No. RTI/ 08087/007/1.2-Vol3F, 18 November 2004. Florida, United States of America. 2004.

RTI International Center for Aerospace Technology. Reusable Launch Vehicle Operations and Maintenance Guideline Inputs and Technical Evaluation Report: Operations - Volume 2, Final Report. RTI Report No. RTI/ 08087/004/Vol2F, 6 February 2004. Florida, United States of America. 2004.

RTI International Center for Aerospace Technology. Reusable Launch Vehicle Operations and Maintenance Guideline Inputs and Technical Evaluation Report: Subsystems - Volume 1, Final Report. RTI Report No. RTI/ 08087/004/Vol1F, 12 January 2004. Florida, United States of America. 2004.

RTI International Center for Aerospace Technology. Reusable Launch Vehicle Operations and Maintenance Guideline Inputs and Technical Evaluation Report: Training - Volume 4, Final Report. RTI Report No. RTI/ 08087/007/2.2-Vol4F, 18 November 2004. Florida, United States of America. 2004.

RTI International Center for Aerospace Technology. Reusable Launch Vehicles Operations and Maintenance Top-Down Analysis - Final Technical Report. RTI Report No. RTI/ 08087.002/Task 1.5-01F, 20 December 2002. Florida, United States of America. 2002.

Japan UAV Association. Safety Standards for Commercial-Use Unmanned Rotary-Wing Aircraft in Uninhabited Areas. Japan UAV Association. http://www.juav.org/contents/juav_safety_standards.pdf. Cited 5 October 2005.

Soanes, C., Spooner, A. and Hawker, S. Oxford Paperback Dictionary, Thesaurus and Wordpower Guide. 9th Edition. Oxford University Press. Oxford, Great Britain. 2001.

SRI Consulting Business Intelligence (SRIC-BI). Disruptive Civil Technologies - Six Technologies with Potential Impacts on US Interests out to 2025. CR 2008-07, April 2008. National Intelligence Council, Director of National Intelligence. United States of America. 2008.

Staff Writers & Sherridan Blackman. Attack of the Drones. Flight Safety Australia, November - December 2002. Australia. 2002.

Systems Engineering Subcommittee. Comparison of Defence Standard 00-56 and ARP 4761/4754. Doc. No : ASSC/330/6/2. Issue 1. July 2002. Avionic Systems Standardisation Committee (ASSC). Surrey, Great Britain. 2002.

Tatelman, T.B. Legal Developments in International Civil Aviation. Congressional Research Service (CRS) Report, Order Code RL33255. American Law Division, Congressional Research Service. Washington, United States of America. 2006.

The Japan UAV Association. Introduction. http://www.juav.org/contents/ introduction_juav.html. Cited 19 October 2005.

Transport Canada. Civil Aviation Scheduled Maintenance Instruction Development Processes Manual. TP 13850E. Transport Canada Civil Aviation Communications Centre (AARC). Ottawa, Canada. 2005.

Transport Canada. Unmanned Air Vehicle Working Group Final Report. Transport Canada (Civil Aviation). http://www.tc.gc.ca/CivilAviation/general/ Recavi/uavworkinggroup.htm#12.1. Cited 6 May 2008.

Turner, A. How Europe Aims to Clean Up the Skies. Flight International 27 May 2008. http://www.flightglobal.com/articles. Cited 28 May 08.

UK CAA. CAP 722 - Guidance for Unmanned Aerial Vehicle (UAV) Operations in UK Airspace. 2nd Edition. Directorate of Airspace Policy, UK Civil Aviation Authority. London, Great Britain. 2004.

UK Department of Transport (Aviation). Glossary of Useful Terms. http://www.dft.gov.uk/stellent/groups/dft_aviation/documents/page/dft_aviation_025899.hcsp. Cited 17 November 2006.

UK Ministry of Defence. JSP553, Military Airworthiness Regulations (2006) Edition 1 Change 5. http://en.wikipedia.org/wiki/Airworthy. Cited 3 September 2008.

UK Ministry of Defence. Ministry of Defence Standard 00-56, Safety Management Requirements for Defence Systems Part 1: Requirements. Issue 4. UK Ministry of Defence. Great Britain. 2007.

UK Ministry of Defence. Ministry of Defence Standard 00-56, Safety Management Requirements for Defence Systems Part 2: Guidance on Establishing a Means of Complying with Part 1. Issue 4. UK Ministry of Defence. Great Britain. 2007.

UK Ministry of Defence. Ministry of Defence Standard 00-970 Part 9, Design and Airworthiness Requirements for Service Aircraft - UAV Systems. Issue 4. UK Ministry of Defence. 2006.

UK Ministry of Defence. Regulation of the Airworthiness of Ministry of Defence Aircraft. JSP 318B. 4th Edition AL2. 1999. (Note: In 2003, JSP 318B was re-issued as JSP 553 as part of the Military Aviation Regulation Document Set. The policy content of the 1st Edition of JSP 553 is identical to that of JSP 318B 4th Edition. http://www.ams.mod.uk/content/docs/avsaf/jsp553.htm. Cited 16 November 2007.)

US Air Force. SMC Systems Engineering Primer & Handbook. 3rd Edition, 29 April 2005. Space & Missile Systems Center, U.S. Air Force. United States of America. 2005.

US Department of Defense. Military Standard: Procedures for Performing a Failure Mode, Effects and Criticality Analysis. 24 November 1980. Washington DC, United States of America. 1980.

US Government Accountability Office. Unmanned Aircraft Systems: Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System . Report to Congressional Requesters. May 2008. United States of America. 2008.

US Navy. Management Manual Guidelines for the Naval Aviation Reliability-Centered Maintenance Process. Navair 00-25-403, 1 July 2005. Naval Air Systems Command, US Navy. United States of America. 2005.

USA Department of Defense. DOD Guide for Achieving Reliability, Availability, and Maintainability. 3 August 2005. Washington, United States of America. 2005.

USA Department of Defense. Operation of the Defense Acquisition System. December 8, 2008. Washington, United States of America. 2008.

USA FAA. 14 CFR Parts 413, 415, and 417. Licensing and Safety Requirements for Launch - Frequently Asked Questions. Docket No. FAA-2000-7953. 21 February 2001. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2001.

USA FAA. 14 CFR, Part 437: Experimental Permits for Reusable Suborbital Rockets: Proposed Rule. 31 March 2006. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2006.

USA FAA. Advisory Circulars (AC) 25.1309–1, System Design and Analysis. 21 June 1988. Federal Aviation Administration. Washington, United States of America. 1988.

USA FAA. Advisory Circulars (AC) 25.1529-1A, Instructions for Continued Airworthiness of Structural Repairs on Transport Airplanes. 20 November 2007. Federal Aviation Administration. Washington, United States of America. 2007.

USA FAA. Advisory Circulars (AC) 25.795–1, Flightdeck Intrusion Resistance, and AC 25.795–2, Flightdeck Penetration Resistance. 15 January 2002. Federal Aviation Administration. Washington, United States of America. 2002.

USA FAA. Advisory Circulars (AC) 25-19, Certification Maintenance Requirements. 28 November 1994. Federal Aviation Administration. Washington, United States of America. 1994.

USA FAA. Advisory Circulars (AC) 25-19. Certification Maintenance Requirements. Federal Aviation Administration. Washington, United States of America. 1994.

USA FAA. Advisory Circulars (AC) 33.75-1A, Guidance Material for 14 CFR§ 33.75, Safety Analysis. 26 September 2007. Federal Aviation Administration. Washington, United States of America. 2007.

USA FAA. Advisory Circulars (AC) 39-8, Continued Airworthiness Assessments of Powerplant and Auxiliary Power Unit Installations of Transport Category Airplanes. 8

September 2003. Federal Aviation Administration. Washington, United States of America. 2003.

USA FAA. Advisory Circulars (AC) 431.35-2A, Reusable Launch and Reentry Vehicle System Safety Process. 20 July 2005. Federal Aviation Administration. Washington, United States of America. 2005.

USA FAA. Advisory Circulars (AC) 437.55-1, Hazard Analysis for the Launch or Reentry of a Reusable Suborbital Rocket under an Experimental Permit. 20 April 2007. Federal Aviation Administration. Washington, United States of America. 2007.

USA FAA. Advisory Circulars (AC) 91-56B, Continuing Structural Integrity Program for Airplanes. 7 March 2008. Federal Aviation Administration. Washington, United States of America. 2008.

USA FAA. Advisory Circulars (AC) 91-60, The Continued Airworthiness of Older Airplanes. 13 June 1983. Federal Aviation Administration. Washington, United States of America. 1983.

USA FAA. Advisory Circulars (AC) 91-82, Management Programs for Airplanes with Demonstrated Risk of Catastrophic Failure Due to Fatigue. 29 April 2008. Federal Aviation Administration. Washington, United States of America. 2008.

USA FAA. Airworthiness Certification of Unmanned Aircraft Systems. Draft Order 8130.UAS. Federal Aviation Administration. Washington, United States of America. 2008.

USA FAA. Compilation of AST Regulations - 14 CFR Chapter III. Prepared by AST. 13 March 2005. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2005.

USA FAA. Concept of Operations for the Next Generation Air Transportation System. Version 2.0, 13 June 2007. Federal Aviation Administration. Washington, United States of America. 2007.

USA FAA. Federal Aviation Regulations Title 14: Aeronautics and Space, Part 1 - Definitions and Abbreviations. Federal Aviation Administration. Washington, United States of America. 2009.

USA FAA. Federal Aviation Regulations Title 14: Aeronautics and Space, Part 21 - Certification Procedures for Products and Parts. Federal Aviation Administration. Washington, United States of America. 2009.

USA FAA. Federal Aviation Regulations Title 14: Aeronautics and Space, Part 25 - Airworthiness Standards: Transport Category Airplanes. Federal Aviation Administration. Washington, United States of America. 2009.

USA FAA. Federal Aviation Regulations Title 14: Aeronautics and Space, Part 29 - Airworthiness Standards: Transport Category Rotorcraft. Federal Aviation Administration. Washington, United States of America. 2009.

USA FAA. Guide to Commercial Reusable Launch Vehicle Operations and Maintenance Version 1.0, March 2005. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2005.

USA FAA. Guide to Commercial Reusable Launch Vehicle Operations and Maintenance. Version 1.0. March 2005. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2005.

USA FAA. Guide to Probability of Failure Analysis for New Expendable Launch Vehicles. Version 1.0, November 2005. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2005.

USA FAA. Guide to Reusable Launch and Reentry Vehicle Reliability Analysis. Version 1.0, April 2005. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2005.

USA FAA. Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety. Version 1.0. July 2006. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2006.

USA FAA. Guide to Verifying Safety-Critical Structures for Reusable Launch and Reentry Vehicles. Version 1.0, November 2005. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2005.

USA FAA. Interim Operational Approval Guidance 08-01, Unmanned Aircraft Systems Operations in the U.S. National Airspace System. Unmanned Aircraft Program Office (AIR-160), Federal Aviation Administration. Washington, United States of America. 2008.

USA FAA. Order 8110.49, Software Approval Guidelines. 3 June 2003. Federal Aviation Administration. Washington, United States of America. 2003.

USA FAA. Order 8110.54, Instructions for Continued Airworthiness: Responsibilities, Requirements, and Contents. 1 July 2005. Federal Aviation Administration. Washington, United States of America. 2005.

USA FAA. Order ND8040.4, Safety Risk Management. 26 June 1998. Federal Aviation Administration. Washington, United States of America. 1998.

USA FAA. Policy AFS-400 UAS Policy 05-01, Unmanned Aircraft Systems Operations in the U.S. National Airspace System - Interim Operational Approval Guidance. 16 September 2005. Federal Aviation Administration. Washington, United States of America. 2005.

USA National Archives and Records Administration. Electronic Code of Federal Regulations (e-CFR). Title 14 - Aeronautics and Space. Chapter III - Commercial Space Transportation, Federal Aviation Administration, Department of Transportation. 12 September 2006.

USAR Working Group (2004). UAV Systems Airworthiness Requirements (USAR). Version 3.0, 20 January 2005. UAV Flight Test Team Manager, Délégation Générale des Armements (DGA). Istres, France. 2005.

UVS International. Non-Military Applications of UAS-WRC. UVS International document supplied by EUROCONTROL to the World Radio Conference, Geneva, Switzerland, 2007. UVS News Flash & Notifications e-mail dated 4 November 2007. Blyenburgh & Co. Paris, France. 2007.

Van Blyenburgh, P. and Butterworth-Hayes, P. UVS International Yearbook. UAV Systems - The Global Perspective 2006/2007. van Blyenburgh & Co. Paris, France. June 2006. p.34 - 36.

Van Blyenburgh, P. and Butterworth-Hayes, P. UVS International Yearbook. UAV Systems - The Global Perspective 2006/2007. van Blyenburgh & Co. Paris, France. June 2006. p.7.

Van Blyenburgh, P. and Butterworth-Hayes, P. UVS International Yearbook. UAV Systems - The Global Perspective 2006/2007. van Blyenburgh & Co. Paris, France. June 2006. pp.8, 12, 26, 34, 156.

Van der Merwe, A.J. Towards a Reusable Process Model Structure for Higher Education Institutions. PhD Thesis. University of South Africa. Pretoria, South Africa. 2005.

Van Duren, E.C.G.J. (Col). Developments in Military Aviation: A Military Aviation Authority Perspective. Host Nation Conference Warsaw, 28 June 2006. Warsaw, Poland. 2006.

Von Backström, T.W. (Prof). E-mail correspondence to A. Maneschijn. 04:40PM, 19 July 2010. Department of Mechanical and Mechatronic Engineering, Stellenbosch University. Stellenbosch, South Africa. 2010.

Walker, J. and Kenagy, R. Co-Chairs RTCA Special Committee 203. Preparing UAV-Related Standards RTCA Special Committee 203. www.access5.aero/site_content/news/pdf/editorial_20apr05_rtca.pdf. Cited 10 October 2005.

Webster's Online Dictionary. "Flight-worthy: An aircraft, missile, or spacecraft is flight-worthy if it is ready and sufficiently sound in all respects to meet and endure the stresses and strains of flight. Source: European Union." http://www.websters-online-dictionary.org/fl/flight-worthy.html. Cited 11 November 2009.

Webster's Online Dictionary. http://www.websters-online-dictionary.org/ definition/operable. Cited 11 November 2009.

Wikipedia Contributors. "Operability", Wikipedia. The Free Encyclopedia, Wikipedia. http://en.wikipedia.org/w/index.php?title=Operability&oldid=320876173. Cited 11 November 2009.

Wikipedia Contributors. 'Systems Engineering Process'. Wikipedia, The Free Encyclopedia. http://en.wikipedia.org/w/index.php? title=Systems_engineering_process&oldid=339443754. Cited 23 March 2010.

Williams, W. & Harris, M. The Challenges of Flight-Testing Unmanned Air Vehicles. Proceedings of the Systems Engineering, Test & Evaluation Conference. October 2002. Sydney, Australia. 2002.

Wilson, E.S. and Locket, R.D. Managing Ageing Aircraft Structures. Proceedings of the 10th Australian International Aerospace Congress incorporating the 14th National Space Engineering Symposium. 29 July - 1 August 2003. Queensland, Australia, 2003.

Zhao, W. Feature-Based Hierarchical Knowledge Engineering for Aircraft Life Cycle Design Decision Support. Ph.D Dissertation. May 2007. School of Aerospace Engineering, Georgia Institute of Technology, Atlanta. Georgia, Uinted States of America. 2007.

Zwick, J. A Multinational Airworthiness Experience. NATO Airborne Early Warning & Control Force Command (NAEW&C FC) presentation. EMAAG/IMAAC 2006, 16 – 18 October 2006. German Air Force Materiel Command. Cologne, Germany. 2006.

APPENDIX A

Table 1. Evaluation of Regulatory Approaches in terms of Regulatory Concepts[1]

Regulatory Concepts	Aviation Sector/Future Scenario			
	Civil	**Military (where applied)**	**Classical Scenario**	**Autonomous Scenario**
Motivation				
Promote key industries	x	x	x	
Promote public acceptance	x		x	x
Ensure essential services	x	x		x
Protect interests	x	x	x	x
Prevent undesirable behaviour	x	x	x	x
Protect future generations	x	x		x
Styles				
Command and Control	x	x	x	x
Self-Regulation				
Market Control	x		x (Civil, manned)	x (Civil, manned)
Direct Action		x	x (Military)	x (Military)
Rights and Liabilities Laws				
Approaches				
Prescriptive	x	x	x (Manned)	x (Manned unique)
Performance based			x (UAS)	x (Manned & UAS generic)
Principle based				x (UAS unique)
Regulatory Effectiveness Criteria				
Airworthiness issues defined	In terms of safety (not uniquely for UAS)	In terms of missions	Yes (for manned aircraft), limited for UAS	Yes (for manned aircraft), dynamically updated for UAS
Government action justified	Yes	Yes	Yes	Yes
Legal basis established	International and national	No international, only a few national	Civil - international and national Military - international mainly for UAS, national limited	International and national, civil and military
Styles and approaches selected	Yes (not for UAS)	Yes	Yes	Yes
Benefits justify cost of regulation	Only *efficient* regulation justified	Only *efficient* regulation justified	Regulation not optimised, cost justification questioned	Benefits from optimised, and for UAS automated, regulation justifies cost
Regulations clear and comprehensible	Not generally	Not generally	Old regulations retain status, new regulations (eg UAS) more clear and comprehensible	Old regulations overhauled. UAS regulations developed 'simple' and logical for automation
Regulator has necessary competencies	Not always	Not always	Performance-based regulations require new competencies	New competencies, including automation competencies, required for performance- and principle based regulations
Compliance achievable	Not always	Not always	Not always	Mostly
Regulator accountable and regulatory system implemented efficiently	Accountability not always enforced, efficiency dependent on budget	Accountability not always enforced, efficiency seldom achieved	Civil - significant improvement wrt UAS Military - some improvement wrt UAS only	Achieved globally for civil manned aircraft, mostly for military manned aircraft, and universally for UAS

Table 2: Evaluation of Technical Scopes of UAS Scenarios[1]

REGULATORY ELEMENT	CLASSICAL SCENARIO - UAS AIRWORTHINESS			AUTONOMOUS SCENARIO - UAS AIRWORTHINESS		
	Scenario Airworthiness Requirements	Current Annex 8 Provisions	Airworthiness Framework Provisions	Scenario Airworthiness Requirements	Current Annex 8 Provisions	Airworthiness Framework Provisions
Definitions and Classifications	UAS specific	-	-	UAS specific	-	-
Procedures	Type certification	x	x	Design certification - automated, per aircraft serial number	-	-
	Production approval	x	x	Production approval - automated, robot based, per aircraft serial number	-	-
	Certificates of airworthiness	x	x	Certificates of airworthiness - automated electronic certificate of airworthiness	-	-
	Continued airworthiness	x	x	Dynamic, continuous airworthiness monitoring against individual UAV's airworthiness database	-	-
	Compliance, Limitations, Risk Management and Safety Information	-	x	Compliance, Limitations, Risk Management and Safety Information	-	x
Airworthiness Requirements	Flight	x	x	Flight	x	x
	Hazard and collision avoidance	-	x	Hazard and collision avoidance	-	x
	Safety equipment and emergency capability	x	x	Safety equipment and emergency capability	x	x
	Structures	x	x	Structures (Principle based)	-	-
	Design and construction	x	x	Design and construction (Principle based)	-	-
	Powerplant and powerplant installation	x	x	Powerplant and powerplant installation (Principle based)	-	-
	Systems, instruments, software and equipment	x	x	Systems, instruments, software, equipment and artificial intelligence (Principle based)	-	-
	Operating limitations and safety information	x	x	Operating limitations and safety information	x	x
	Continued airworthiness	x	x	Continued airworthiness (Principle based)	-	-
	Security	x	x	Security (Principle based)	-	-
	Communication system	-	x	Communication system and networks	-	-
	Offboard elements/ equipment	-	x	Offboard elements/ equipment	-	x

Table 3. The Original Framework for UAS Airworthiness Requirements[1]

PARTS	SECTIONS	SUB-SECTIONS
(1)	(2)	(3)
PART I - DEFINITIONS AND CLASSIFICATIONS	DEFINITIONS	
	CLASSIFICATIONS	
PART II - PROCEDURAL REQUIREMENTS		General; Approval and Certification of Design, Production and Maintenance; Compliance with Airworthiness Requirements; Continued Aerial Vehicle and Supporting Element Airworthiness; Airworthiness Approvals and Certificates; Limitations, Risk Management and Safety Information
PART III - UNMANNED AERIAL VEHICLE AND SYSTEM AIRWORTHINESS REQUIREMENTS	GENERAL	
	FLIGHT	General; Aerial Vehicle Performance; Flight Characteristics; Flight Management Systems; Controllability and Manoeuvrability; Stability; Stalls; Spinning; Ground Handling Characteristics; Miscellaneous Flight Requirements; Assisted Take-Off/Launch; Landing/Recovery System; Emergency Landing/Recovery
	HAZARD AND COLLISION AVOIDANCE	Hazard and Collision Avoidance Systems
	SAFETY EQUIPMENT AND EMERGENCY CAPABILITY	Emergency Systems
	STRUCTURES	General; Flight Loads; Structures; Control Surface/Element Loads and Control System Loads; Horizontal Tail Surfaces/Pitch Control Elements; Vertical Surfaces/Yaw Control Elements; Ailerons/Roll Control Elements; Special Devices; Ground Loads; Emergency Landing Conditions; Fatigue Evaluation; Catapult Assisted and Rocket Assisted Take-Off Aerial Vehicle; Parachute Recovery System
	DESIGN AND CONSTRUCTION	General; Flight Management Systems; Structures; Rotors; Control Surfaces/Flight Control Devices; Control Systems; Landing Gear; Useful Payload and Equipment Accommodations - External and Internal; Pressurisation and Environmental Systems; Fire Protection; Miscellaneous; Launch Systems; Landing/Recovery Systems; Floats and Hulls; Emergency Systems; Electrical Systems; Software; Navigation and Communication Systems; Mechanical Systems; Payload/Cargo; Supporting Elements/Equipment
	POWERPLANT AND POWERPLANT INSTALLATION	General; Fuel System; Energy Storage Systems; Oil System; Cooling; Liquid Cooling; Induction System; Exhaust System; Power plant Controls and Accessories; Power plant Fire Protection; Power plant Systems
	SYSTEMS, INSTRUMENTS, SOFTWARE AND EQUIPMENT	General; Measuring Devices; Aerial Vehicle Electrical Systems and Equipment; Software; Lights; Safety Equipment and Emergency Capability; Miscellaneous Equipment; Automatic Take-Off and Landing System; Communication and Navigation Equipment
	OPERATING LIMITATIONS AND SAFETY INFORMATION	General; Information, Markings and Placards; Aerial Vehicle and System Manual
	CONTINUED AIRWORTHINESS	General; Aerial Vehicle Continuous Airworthiness; Supporting Element Continuous Airworthiness
	SECURITY	Aerial Vehicle Security; Supporting Element Security
	COMMUNICATION SYSTEM	Communication System; Command and Control Data Link
	OFFBOARD ELEMENTS/EQUIPMENT	General; Remote Control Station; Data Displayed in the Remote Control Station; Controls; Indicators and Warnings; Information, Markings and Placards; Miscellaneous; Control Station System Manual

APPENDIX B

Table 1. The UAS Operability Framework

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART I - DEFINITIONS AND CLASSIFICATIONS			
	General		
	Definitions		
	Classifications		
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Introduction		
	General Criteria	Applicability	
		Types of Approvals and Certifications	Engineering Approvals; Regulatory Approvals and Certifications
		Administration	Engineering Processes
		Safety Assurance	General
		Safety Assurance	General
		Training	General
		Licensing	General
	Procedures for Approvals and Certifications Associated with UAS Operability	General	Applicability; Eligibility; Designated Authorisations; Application for Approvals and Certificates; Applicable Requirements; Special Conditions; Issuing of Approvals and Certificates; Approval/Certificate Holder Responsibilities; Deviations; Non-compliance; Changes Requiring New Approvals and Certificates; Inspections by Authority; Suspension/Cancellation of Approvals/Certificates
	Criteria for Initial and Continued Compliance with Operability Requirements	Introduction	
		Initial Compliance	Qualification; Design Type Certification; Engineering Process
		Continued Compliance	Continued Compliance Process and Procedures
	Risk Management	Introduction	
		Risk Management Criteria	Hazard Identification; Risk Assessment; Risk Control Plan; Risk Acceptance; Risk Tracking
UAS OPERABILITY FRAMEWORK PART III - UAS OPERABILITY CRITERIA			
UAS OPERABILITY FRAMEWORK PART IIIA - SYSTEM OF SYSTEMS OPERABILITY CRITERIA			
	Introduction	Engineering Approach Criteria; Engineering Process Criteria	
	System Operability	Achieving Initial System-level Operability	Define Missions and System Requirements; Conceptualise System and Constituent Sub-Systems; Finalise System of Systems and Sub-system Designs; Integrate System of Systems Sub-systems; Test and Evaluate System of Systems; Acceptance of System of Systems; Confirm System of Systems Operability
		Maintaining Continued System-level Operability	Acceptance of System of Systems; Confirm System of Systems Operability; Monitor and Maintain System of Systems Continued Operability; Monitor and Maintain Sub-system Continued Operability; Confirm Post-maintenance System of Systems Operability; System of Systems Termination, Decommissioning and Disposal
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Introduction		
	General	Applicability	
		Operations and Missions of the UAS Airborne Sub-systems	
	Flight and Ground Handling	General	Verification and Validation; Aircraft Principles of Flight; Aircraft Weights; Centre of Gravity Range and Limits; Removable Ballast; Payload and Payload Distribution; Load Distribution Limits; Airborne Sub-systems other than the Aircraft
		Aircraft Performance	General; Minimum Flight Speed; Stall Speed; Take-off/Launch Performance; Climb Performance; Glide Performance; Landing/Recovery Performance; Cruise Performance; Manoeuvring Performance and Limitations; Loitering Performance; Combat Performance and Limitations; Maximum Speed; Endurance; Range; Performance of Airborne Sub-systems other than the Aircraft
		Flight Characteristics	General; Aircraft Aerodynamics; Aircraft Flight Characteristics; Flight Characteristics of Airborne Sub-systems other than the Aircraft
		Controllability and Manoeuvrability	General; Flight Control System; Minimum Control Speed; Trim
		Stability	Stability Characteristics
		Stalls	Stalls; Stall Protection
		Spinning	Spinning
		Surface Handling Characteristics	Surface Handling; Stability and Control; Operation from Unprepared Surfaces

		Miscellaneous Requirements	Vibration and Buffeting; High Speed Characteristics; Other Novel Characteristics
		Assisted Take-Off/Launch	Take-off/Launch Safety; Take-off/Launch System Interfacing; Take-off/Launch Performance; Transition to Normal Flight; Control of Aircraft During Take-off/Launch
		Assisted Landing/Recovery	Landing/Recovery Safety; Aircraft Performance before Landing/Recovery; Landing/Recovery System Interfacing; Control of Aircraft During Landing/Recovery
		Emergency Landing/Recovery	Emergency Landing/Recovery Safety; Emergency Landing/Recovery System Interfacing; Control of Aircraft during Emergency Landing/Recovery
	Flight and Surface Operation Load Considerations	Flight Loads	General; Flight Loads and Flight Load Considerations
		Control System Loads	General; Primary Control System Loads; Secondary Control System Loads; Limit Control Forces and Torques; Surface Gust Conditions
		Pitch Control Device Loads	General; Pitch Control Device Loads; Balancing Loads; Unsymmetrical Loads; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Yaw Control Device Loads	General; Yaw Control Device Loads; Balancing Loads; Unsymmetrical Loads; Outboard Fins and Winglets; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Roll Control Device Loads	General; Roll Control Device Loads; Balancing Loads; Unsymmetrical Loads; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Surface Operation Loads	General; Surface Operation Loads and Surface Operation Load Considerations
		Emergency Conditions	General
		Catapult Assisted and Rocket Assisted Take-Off Loads	Launch Loads; Trolley or Shuttle Loads; Rocket Assisted Take-off Loads
		Parachute Recovery System Loads	Parachute Recovery Loads; Extracting Devices; Sacrificial Elements; Aircraft Dragging on the Surface
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Flutter; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors
		Flight Management System	Flight Management System; Flight Safety System; Flight Control System; Autonomy; Health Monitors and Data Recorders
		Structures	Primary Structural Elements; Other Structural Elements; Flight Controls; Onboard Launch System Elements; Onboard Recovery System Elements
		Rotors	General
		Flight Control Devices	General; Surface Gust Conditions
		Control Systems	General
		Landing Gear	General
		Payload and Equipment Accommodations - Internal and External	Internal Compartments; External Equipment Installations; External Payload Hardpoints
		Pressurisation and Environmental Control Systems	Pressurised Compartments; Environmental Control Systems
		Fire Protection	General; Fire Extinguishing Systems
		Miscellaneous	Levelling Means; Ballast Provisions
		Floats and Hulls	General
		Emergency Systems	Emergency Recovery Systems; Flight Termination Systems
		Electrical Systems	General
		Software	General; Software Maintenance
		Navigation and Communication Systems	General
		Mechanical Systems	General
	Powerplant and Powerplant Installation	General	Powerplant Type; Rotor and Power Transmission Systems
		Powerplant Systems	General; Transmissions and Gearboxes
		Fuel Systems	General; In-flight Refuelling Systems
		Energy Storage Systems	General
		Powerplant Fire Protection	General
		Powerplant Controls and Accessories	Powerplant Controls; Powerplant Accessories
	Hazard and Collision Avoidance	Hazard Avoidance Systems	General
		Collision Avoidance Systems	General
	Avionics, Instruments and Equipment	General	Software; Software Maintenance
		Communication and Navigation Equipment	Communication Equipment; Command and Control Data Link; Navigation Equipment
		Instruments and Sensors	General
		Automatic Take-off and Landing Systems	General; Manual and Automatic Abort Functions
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Safety Equipment and Emergency Capabilities	Safety Equipment; Emergency Capabilities
		Miscellaneous Equipment	General
	Operating Limitations, Safety Information and System Manual	Operating Limitations	General
		Markings and Placards	General
		Aircraft/Airborne Sub-system Manual	General
	Continued Operability and Airworthiness	Continued Operability and Airworthiness Requirements	General
	Security	Aircraft/Airborne Sub-system Security	General

UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Introduction		
	General	Applicability	
		Functions of Non-Airborne Sub-systems	
	Operating and Functional Characteristics	General	Verification and Validation
		Take-off/Launch System	General; Take-off/Launch System Safety
		Landing/Recovery System	General; Landing/Recovery System Safety; Emergency Landing/Recovery Safety
		Remote Control Station	General; Remote Control Station Safety
		Other Non-Airborne Support Systems	General; Support System Safety
	Load Considerations	Take-off/Launch System Loads	General
		Landing/Recovery System Loads	General
		Remote Control Station Loads	General
		Other Non-Airborne Support System Loads	General
		Emergency Conditions	General
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors; Transportability; Storage Provisions
		Structures	Primary Structural Elements; Other Structural Elements
		Controls and Equipment	General
		Internal Environment Control Systems	General
		Fire Protection	General; Fire Extinguishing Systems
		Environmental Hazards Protection	General
		Emergency Systems	General
		Electrical Systems	General
		Software	General; Software Maintenance
		Mechanical Systems	General
		Powerplants	General
	Instruments and Equipment	General	Software; Software Maintenance
		Communication Equipment	Communication Equipment; Command and Control Data Link
		Instruments and Sensors	General
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Safety Equipment and Emergency Capabilities	Safety Equipment
		Miscellaneous Equipment	General
	Operating Limitations, Safety Information and System Manuals	Operating Limitations	General
		Markings and Placards	General
		System Manuals	General
	Continued Operability	Continued Operability Requirements	General
	Security	Non-Airborne Sub-system Security	General
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Introduction		
	General	Applicability	
	General and Functional Characteristics	General	Verification and Validation
		Cargo Payloads	General; Payload Safety
		Functional Payloads	General; Payload Safety; Safety during UAS Emergency
	Load Considerations	Cargo Payloads	General
		Functional Payloads	General
		Emergency Conditions	General
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors; Transportability; Storage Provisions
		Structures	Primary Structural Elements; Other Structural Elements
		Controls and Equipment	General
		Fire Protection	General
		Environmental Hazards Protection	General
		Emergency Systems	General
		Electrical Systems	General
		Software	General; Software Maintenance
		Mechanical Systems	General
	Instruments and Equipment	General	Software; Software Maintenance
		Communication Equipment	Communication Equipment; Data Link
		Instruments and Sensors	General
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Miscellaneous Equipment	General
	Operating Limitations, Safety Information and System Manuals	Operating Limitations	General
		Markings and Placards	General
		System Manuals	General
	Continued Operability	Continued Operability Requirements	General
	Security	Payload Security	General

APPENDIX C

Populated UAS Operability Framework Tables

Notes

- Appendix C contains the populated UAS operability framework. However, due to its comprehensive scope, the framework had to be separated into practical sub-units to enable introducing each primary element and describing its purpose in a manageable manner.
- By sub-dividing the framework, its clarity and utilisation has been enhanced and the inclusion of position-indicators for each sub-unit allows for easy recognition of the placement and relevance of the sub-unit in the overall operability framework.
- The sub-division was carried out in hierarchical order with the framework divided into its parts, each part divided into its sub-parts, each sub-part divided into its sections, and each section divided into sub-sections.
- At the start of each primary part of the framework, a summary structure of the part is included.
- The operability criteria that were developed for populating the framework were developed for each lowest hierarchical element in each sub-unit, with the lowest level being operability criteria for each sub-section.
- The operability criteria were developed and tailored to be applicable and appropriate for each hierarchical element, but as much similarity and consistency as was reasonably practical were kept for criteria that addressed similar element subjects. Thus, although there may appear to be substantial repetition of the operability criteria, each entry was tailored for its specific hierarchical element.
- Each hierarchical element that was found to be significant for the development of continued operability criteria and instructions for a UAS were marked accordingly in this Appendix. In the development of a UAS, each hierarchical element that was selected for inclusion in the UAS operability requirements and which was marked as a continued-operability significant element, must be reviewed and included in the continued operability instructions for the UAS.

C-1. UAS OPERABILITY FRAMEWORK PART I: DEFINITIONS AND CLASSIFICATIONS

Although the UAS Operability Framework is intended to be a framework of engineering criteria for UAS operability, its co-ordination with regulatory requirements remains a requirement to ensure the most effective integration of UAS operations into regulated airspace. This part therefore serves as an instrument in which definitions of UAS-specific terminology, and UAS type classifications can be included, both from an engineering perspective, as well as in co-ordination with regulatory guidelines.

The emphasis of this part is on terminology relevant to UAS operability (rather than only airworthiness[2,3,4,5,6,7,8,9,10,11]), and classifications for UAS, airborne sub-systems of UAS, non-airborne sub-systems of UAS and UAS payloads.

The table below gives an overview of the scope of this part as included in the Framework for the purposes of this thesis.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART I - DEFINITIONS AND CLASSIFICATIONS			
	General		
	Definitions		
	Classifications		

The criteria relevant to the sub-parts of this part are presented in the following paragraphs.

C-1.1 Sub-Part: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART I - DEFINITIONS AND CLASSIFICATIONS			
	General		

This sub-part must introduce the part and describe its purpose and applicability in respect of the UAS under consideration. The detail required in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-PART	OPERABILITY CRITERIA
General	Introduce this part and describe its purpose and applicability.

C-1.2 Sub-Part: Definitions

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART I - DEFINITIONS AND CLASSIFICATIONS			
	Definitions		

This sub-part must list definitions of terminology in respect of the UAS under consideration. The detail required in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-PART	OPERABILITY CRITERIA
Definitions	Although the definitions do not contribute to the operability status or operability of the UAS, they do contribute to the understanding of the characteristics, functioning and operation of the UAS under consideration. Definitions of terminology that are relevant and/or unique to the UAS must therefore be listed in this sub-part. Industry and statutory/regulatory generated definitions and terms must be continuously monitored and incorporated in this sub-part as and when relevant.

C-1.3 Sub-Part: Classifications

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART I - DEFINITIONS AND CLASSIFICATIONS			
	Classifications		

The classification of aircraft types into different categories is used in the regulatory domain to reduce the number of different sets of airworthiness requirements that must be developed by grouping similar types and classes of aircraft together. Various organisations and regulating authorities have already initiated processes of UAS classification. However, global co-ordination and commonality in this regard has not yet been achieved[1,2,4,11,12,13,14,15,16,17]. The classification of UAS must, however, provide for the effective and appropriate classification of at least the following:

- different types of UAS;
- different types of aircraft and other airborne sub-systems of UAS;
- different types of non-airborne sub-systems of UAS, including different types of remote control stations; and
- different types of cargo and functional UAS payloads.

Since standardised classifications for UAS have not been agreed upon globally, and to facilitate acceptance of the UAS under consideration by the majority of authorities, this sub-part must be used to identify the types of UAS, airborne sub-systems, non-airborne sub-systems and payloads of the UAS under consideration. The detail required in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-PART	OPERABILITY CRITERIA
Classifications	As with definitions, classifications do not contribute to the operability status or operability of the UAS, but they do contribute to the understanding and acceptance of the characteristics, functioning and operation of the UAS under consideration by the industry and relevant regulating authorities. This sub-part must therefore be used to identify and describe the relevant types of sub-systems of the UAS under consideration from the following: - the type of UAS; - the types of aircraft and other airborne sub-systems of the UAS; - the types of non-airborne sub-systems of the UAS, including the type of remote control station; and - the types of cargo and functional payloads to be carried by the UAS aircraft.

	The description of the types must be in a format that is consistent with, or adaptable to, the different classification systems applied by the various regulating authorities. Industry and statutory/ regulatory generated classifications must also be continuously monitored and recognised in this sub-part, as and when relevant.

C-2. UAS OPERABILITY FRAMEWORK PART II: PROCEDURAL CRITERIA

This part addresses procedural criteria for achieving and maintaining UAS operability, where the criteria are aligned with typical regulatory approaches. The scope of this part includes criteria relevant to the operability of the UAS as a system, its airborne sub-systems, its non-airborne sub-systems, and its payloads.

The criteria described in this part are usually associated with the regulatory domain. However, the engineering domain can apply these criteria equally effectively as self-regulating measures to ensure the efficient development, deployment and continued operation of UAS, particularly when such UAS are not subject to formal regulation.

Whether regulated or not, it must also be recognised that the criteria included in this part will not always be applicable to all UAS. In the application of the criteria, the engineering domain will need to use sound judgement in selecting the appropriate and relevant criteria for each UAS under consideration. Such judgement should be based on considerations of both the operability and the safe operation of the UAS. The table below gives an overview of the scope of this part as included in the Framework for the purposes of this thesis.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Introduction		
	General Criteria	Applicability	
		Types of Approvals and Certifications	Engineering Approvals; Regulatory Approvals and Certifications
		Administration	Engineering Processes
		Safety Assurance	General
		Safety Assurance	General
		Training	General
		Licensing	General
	Procedures for Approvals and Certifications Associated with UAS Operability	General	Applicability; Eligibility; Designated Authorisations; Application for Approvals and Certificates; Applicable Requirements; Special Conditions; Issuing of Approvals and Certificates; Approval/Certificate Holder Responsibilities; Deviations; Non-compliance; Changes Requiring New Approvals and Certificates; Inspections by Authority; Suspension/Cancellation of Approvals/Certificates
	Criteria for Initial and Continued Compliance with Operability Requirements	Introduction	
		Initial Compliance	Qualification; Design Type Certification; Engineering Process
		Continued Compliance	Continued Compliance Process and Procedures
	Risk Management	Introduction	
		Risk Management Criteria	Hazard Identification; Risk Assessment; Risk Control Plan; Risk Acceptance; Risk Tracking

The criteria relevant to the sub-parts of this part are presented in the following paragraphs.

C-2.1 Sub-Part: Introduction

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Introduction		

This sub-part must introduce the part and describe its purpose and scope in respect of the UAS under consideration. The detail required in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-PART	OPERABILITY CRITERIA
Introduction	Introduce this part and describe its purpose and scope. From an engineering perspective, it is important to indicate that this part serves two purposes, including: - addressing procedural requirements to ensure the efficient development, deployment and operation of the UAS and its sub-systems, whether the UAS is regulated or not; and - guiding the development of procedures that stem from this part for the engineering environment, to be aligned with typical regulatory requirements for aviation safety.

C-2.2 Sub-Part: General Criteria

This sub-part must contain general procedures associated with the operability of the UAS and sub-systems under consideration. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	General Criteria	Applicability	
		Types of Approvals and Certifications	Engineering Approvals; Regulatory Approvals and Certifications
		Administration	Engineering Processes
		Safety Assurance	General
		Safety Assurance	General
		Training	General
		Licensing	General

The operability criteria for the sections of this sub-part are given in the following paragraphs.

C-2.2.1 Section: Applicability

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	General Criteria	Applicability	

This section describes the applicability of the criteria and resulting procedures to the UAS and sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SECTION	OPERABILITY CRITERIA
Applicability	To ensure clarity regarding the application of the criteria and procedures of this sub-part, the example of aerospace safety regulations[5, 9,16,18,19] is applied. This section therefore defines to what extent the criteria and procedures of this sub-part apply to the UAS under consideration.

C-2.2.2 Section: Types of Approvals and Certifications

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	General Criteria	Types of Approvals and Certifications	Engineering Approvals; Regulatory Approvals and Certifications

This section describes the types of approvals and certifications that will apply to the UAS and sub-systems under consideration. Where the UAS is not subject to regulation, this section should be applied for self-regulation in the engineering domain to prescribe the approval and certification procedures that are to be used internally by the relevant organisation. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
Engineering Approvals	Typical engineering approvals required to ensure UAS operability in the engineering domain may include[10,13,19,20,21,22,23]: - concept and prototype design approval; - engineering and test programme approvals; - prototype construction approval, test and evaluation approvals; - final design approval; - documentation approval; - production approvals; - maintenance programme approval; and - design change, maintenance, modification and repair approvals.
Regulatory Approvals and Certifications	Under regulation, the airworthiness-related approvals and certifications that may apply to the UAS under consideration include one or more of the following[2,3,4,9,10,11,13,19,21,22,23,24]: - design approval of the aircraft; - airworthiness approvals for prototype and experimental aircraft; - type certification of the aircraft; - production approvals for manufacturing type certified aircraft; - airworthiness certification of each aircraft manufactured under a type certificate; - approval and certification of maintenance programmes; - approval and certification of maintenance, modification and repair work; - approval and certification of continued airworthiness programmes; - approval and certification of airworthiness-related engineering and training facilities; and - approval of airworthiness-related training programmes and certification of airworthiness-related personnel.

C-2.2.3 Section: Administration

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	General Criteria	Administration	Engineering Processes

The administration of engineering processes[25] does not contribute directly to the operability of a UAS, but is nevertheless necessary to ensure that these processes and associated activities are carried out in an orderly and accountable manner, and consistently in accordance with prescribed engineering procedures and regulatory requirements.

This section identifies criteria in respect of administrative procedures that typically apply in the process of achieving and maintain operability of the UAS and sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
Engineering Processes	The administration of engineering processes and procedures related to UAS operability will typically include[13,20,25]: - management of engineering and organisational policies for the roles, requirements and effects of UAS operability; - documenting engineering, test and evaluation policies, processes and procedures; - management of engineering processes; - configuration management and control; - quality management; - management of test and evaluation processes; - management of processes related to regulatory requirements, including, amongst others, preparation of documented compliance evidence, applications for approvals and certifications, applications for aircraft registrations, and applications for related personnel training approvals and personnel certifications; and - management of training, approvals, certifications and competencies of UAS operability-related personnel.

C-2.2.4 Section: Safety Assurance

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	General Criteria	Safety Assurance	General

A primary objective of regulating aviation[1,12,18,20] and space[5,25] activities is to ensure the safety of public and property. Safety assurance demonstrates that a UAS and its sub-systems are sufficiently safe not to endanger public or property. Amongst others, a functional hazard analysis of the UAS and sub-systems under consideration must be carried out, from which different levels of risks are assigned to the UAS and sub-systems[26].

This section provides for the carrying out of a safety assurance assessment of the UAS and sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
General *<Continued Operability Entity>*	A safety assurance assessment, followed by appropriate safety and redundancy design changes, should be carried out for each new UAS and/or sub-system design or design change. When the initial safety assurance level has been demonstrated to be acceptable for the UAS and/or sub-systems under consideration, the continued operability programmes for the UAS and sub-systems must maintain the accepted safety assurance level. The continued operability programmes must therefore be reviewed and revised regularly to ensure that effects of UAS and sub-system changes are incorporated in order to maintain the accepted safety assurance level. Alternatively, new safety assurance assessments must be carried out when UAS and sub-system changes are sufficiently significant to invalidate the original safety assurance level.

C-2.2.5 Section: Mission Assurance

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	General Criteria	Safety Assurance	General

Aviation and space regulations usually either prohibit an unsafe aircraft or spacecraft from flying, or require the crew of such an aircraft or spacecraft to terminate a flight immediately and as safely as possible when an unsafe condition is detected during a mission[5,18,25]. As is the case with reusable launch vehicles (RLVs)[5,25], many UAS missions, such as very long surveillance missions, may require appropriate precautions to be taken on- and off-board the aircraft to ensure the mission can be completed, even in the event of unsafe conditions and/or failures. The missions, and therefore the mission assurance provisions and precautions, should be such that it can reasonably be expected that the safety of public and property would not be compromised in the event of unsafe or failure events.

This section provides for the defining of appropriate precautions to ensure mission assurance for the UAS and sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
General *<Continued Operability Entity>*	To account for special mission conditions and requirements, appropriate provisions and precautions must be defined to achieve and maintain the required levels of mission assurance. Since mission conditions and requirements usually differ, the provisions and precautions must be tailored to ensure mission assurance for each mission.

C-2.2.6 Section: Training

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	General Criteria	Training	General

As is the case with reusable launch vehicles (RLVs)[5,25], the development, configuration, operation, maintenance and continued operability of a UAS and sub-systems are subject to change for each flight and mission. Following the traditional, relatively static system of training in disciplines and skills associated with the aviation engineering domain, personnel associated with ensuring the initial and continued operability of the UAS and sub-systems under consideration, should therefore receive additional and continued training relevant and unique to the respective UAS and sub-systems.

This section provides for the development of appropriate additional engineering training relevant to the UAS and sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
General *<Continued Operability Entity>*	Appropriate specialised engineering training programmes in the technical and engineering disciplines associated with the UAS and sub-systems under consideration, must be developed and conducted. The subject material should be relevant and unique to the UAS and sub-systems under consideration.

C-2.2.7 Section: Licensing

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	General Criteria	Licensing	General

Licensing under regulation applies not only to personnel, but also to operators, engineering and training organisations, and facilities[5,20,25,27]. Where the operability of a UAS is regulated, the initial and the continued operability of that UAS must be supported by, and based on, appropriately licensed and approved personnel, organisations, operators and facilities.

This section provides for the training and licensing of technical and engineering personnel associated with the UAS and sub-systems under consideration, when required under regulation. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	**OPERABILITY CRITERIA**
General <*Continued Operability Entity*>	All technical and engineering personnel associated with the operability of a UAS must, if required by regulation, be appropriately trained and licensed. Appropriate procedures and facilitation for training and licensing of the relevant personnel must be defined, developed and implemented.

C-2.3 Sub-Part: Procedures for Approvals and Certifications Associated With UAS Operability

This sub-part must contain general procedures relevant to obtaining and maintaining approvals and certifications associated with the operability of the UAS airborne system and sub-systems under consideration, when required by regulations. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Procedures for Approvals and Certifications Associated with UAS Operability	General	Applicability; Eligibility; Designated Authorisations; Application for Approvals and Certificates; Applicable Requirements; Special Conditions; Issuing of Approvals and Certificates; Approval/Certificate Holder Responsibilities; Deviations; Non-compliance; Changes Requiring New Approvals and Certificates; Inspections by Authority; Suspension/Cancellation of Approvals/Certificates

The operability criteria for this sub-part are given in the following paragraph.

C-2.3.1 Section: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Procedures for Approvals and Certifications Associated with UAS Operability	General	Applicability; Eligibility; Designated Authorisations; Application for Approvals and Certificates; Applicable Requirements; Special Conditions; Issuing of Approvals and Certificates; Approval/Certificate Holder Responsibilities; Deviations; Non-compliance; Changes Requiring New Approvals and Certificates; Inspections by Authority; Suspension/Cancellation of Approvals/Certificates

This section describes criteria that are typically associated with obtaining and maintaining approvals and certifications associated with the operability of the UAS and sub-systems under consideration, when required under regulation. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
Applicability	The applicability of regulations on the UAS and sub-systems under consideration must be established and recorded.
Eligibility	The eligibility requirements for obtaining approvals and certifications from the relevant regulating authority for the UAS and sub-systems under consideration, must be established and procedures must be implemented to ensure that the requirements are complied with.
Designated Authorisations	It is common practice for a regulating authority to designate suitable organisations and appropriately qualified and competent persons to perform specific specialised functions on behalf of the authority[24, 28]. Where necessary and relevant, appropriate organisations and personnel associated with the UAS and sub-systems under consideration, should be designated as representatives of the regulating authority.
Application for Approvals and Certificates	Appropriate procedures must be developed and implemented to apply, in the required format[2,5,22,24,27], to the relevant regulating authority for approvals and certifications associated with the operability of the UAS and sub-systems under consideration.
Applicable Requirements	Regulatory requirements[2,5,13,19,22,24,27] associated with UAS and sub-system operability approvals and certifications will typically include: - organisational, procedural, managerial, personnel, safety, and quality assurance requirements for engineering design, test, manufacture and maintenance; - infra-structure, services, procedural, managerial, personnel, safety, and quality assurance requirements for engineering facilities, such as test facilities; - design, testing, manufacturing and maintenance requirements for UAS, UAS sub-systems, and components; and - specific requirements, not otherwise prescribed, to ensure the initial and continued operability of the UAS and sub-systems under consideration. Appropriate procedures must be developed and implemented to ensure compliance with the relevant requirements.

Special Conditions	In addition to the applicable requirements, special conditions[2,5,13,19,22,24,27] may be prescribed by the relevant regulating authority for the UAS and sub-systems under consideration. Appropriate procedures must be developed and implemented to ensure compliance with the special conditions.
Issuing of Approvals and Certificates	An appropriate quality auditing procedure must be implemented to ensure that all requirements and conditions for the issuing of operability approvals and certificates for the UAS and sub-systems under consideration by the regulating authorities, have been complied with.
Approval/Certificate Holder Responsibilities	Appropriate procedures must be developed and implemented to ensure that the duties and responsibilities assigned to each approval or certificate holder by the regulating authority, are carried out in accordance with the requirements of the relevant regulations[13,22,24,27].
Deviations	Manufacturing deviations from approved engineering designs should be reviewed, evaluated and decided on in accordance with regulatory requirements[13,22,24,27] and procedures on a case-by-case basis.
Non-compliance	Each non-compliance with regulatory requirements must be evaluated and decided on by the regulating authority in accordance with regulatory requirements[13,22,24,27] and procedures.
Changes Requiring New Approvals and Certificates	Appropriate procedures must be developed and implemented to ensure that changes made to the UAS and/or sub-systems under consideration, are evaluated in accordance with regulatory requirements to establish whether new approvals or certifications are required as a result of the changes[13, 24,27].
Inspections by Authority	Regulating authorities may carry out inspections of organisations, facilities and UAS in accordance with regulatory requirements[13, 24,27]. Procedures must be implemented to enable such inspections to be carried out with the minimum of disruption to normal activities and operations.
Suspension/Cancellation of Approvals/Certificates	Regulating authorities may, in accordance with regulatory requirements[13, 24,27], suspend or cancel approvals and certificates associated with the operability of the UAS and sub-systems under consideration. Procedures must be implemented to address such suspensions or cancellations in accordance with the prescribed procedures and requirements.

C-2.4 Sub-Part: Criteria for Initial and Continued Compliance with Operability Requirements

This sub-part must contain general procedures associated with achieving and maintaining compliance with the operability requirements relevant the UAS airborne sub-systems under consideration. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Criteria for Initial and Continued Compliance with Operability Requirements	Introduction	
		Initial Compliance	Qualification; Design Type Certification; Engineering Process
		Continued Compliance	Continued Compliance Process and Procedures

The operability criteria for the sections of this sub-part are given in the following paragraphs.

C-2.4.1 Section: Introduction

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Criteria for Initial and Continued Compliance with Operability Requirements	Introduction	

This section describes the objectives and scope of this sub-part in respect of achieving and maintaining compliance with the operability requirements relevant the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SECTION	OPERABILITY CRITERIA
Introduction	The procedures developed under this sub-part must ensure that initial and continued compliance with the operability requirements relevant to the UAS and sub-systems under consideration, is achieved in accordance with a defined and controlled set of engineering and operating specifications. For regulated UAS, compliance with regulatory requirements should be included as part of the engineering and operating specifications. Whether regulated or not, initial and continued compliance with operability requirements form part of the life cycle of the UAS. From an engineering perspective, the life cycle management process suggested by the Parametric Technology Corporation[29] in Figure C-1 provides useful guidance towards developing and implementing appropriate processes and procedures relevant to this sub-part.

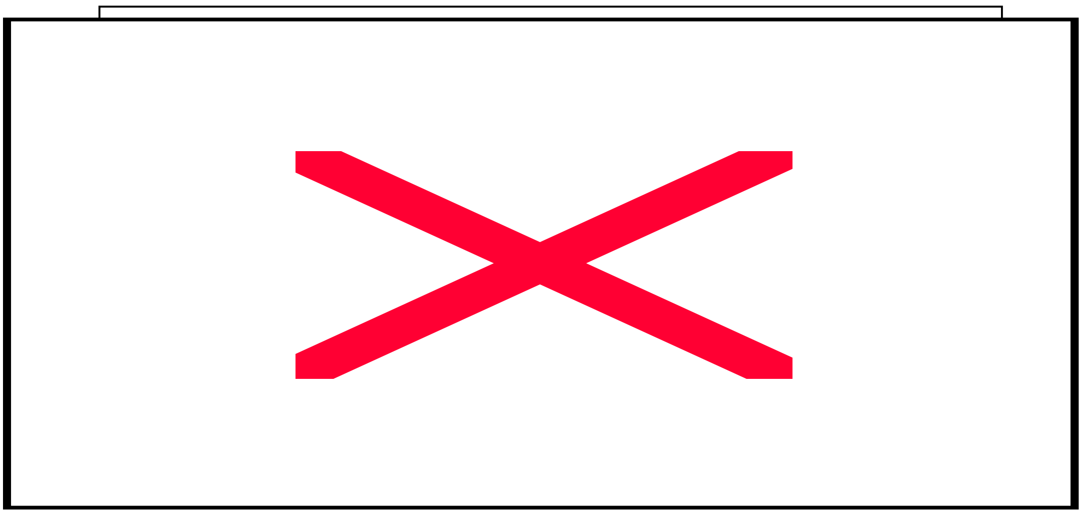

Figure C-1. The Parametric Technology Corporation Closed-Loop Approach to Total Life Cycle Systems Management (reproduced with acknowledgement) [29].

C-2.4.2 Section: Initial Compliance

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Criteria for Initial and Continued Compliance with Operability Requirements	Initial Compliance	Qualification; Design Type Certification; Engineering Process

This section describes the procedures to ensure that initial compliance with the relevant operability requirements is achieved for the UAS and sub-systems under consideration. Initial compliance with UAS operability requirements in accordance with either product specifications or regulatory requirements is the process by which the developer of a system or product must demonstrate, by means of analysis, tests or similarity, that the system or product complies with the relevant specifications and/or regulations. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
Qualification	The process of verifying initial compliance with the specifications[30] for a system/product, and validating the system/product against the intended utilisation objectives[30], is typically known as the qualification process[22]. Qualification of the UAS and sub-systems under consideration is therefore the demonstration that the UAS complies with specifications for: - the operability of the UAS as a system; - the airworthiness of the airborne sub-systems; - the operability of the non-airborne sub-systems; - operational and mission capabilities[22]; - reliability[22]; - availability[22]; - maintainability[22]; - regulatory certification, when applicable; and - any other specification that the developer, the client or the regulator may include as part of the UAS and sub-system specifications.
Design Type Certification	When a UAS or sub-system is subject to regulation, the initial compliance qualification process must include the appropriate regulatory approval and/or certification of the UAS and sub-systems in respect of regulatory requirements. In particular, the type certification of a design is the process of showing initial compliance with airworthiness regulations with the objective of having the design type certified by a competent regulating authority[9,22,24,28].
Engineering Process	An appropriate engineering process, such as systems engineering, must be developed and implemented to ensure compliance with initial and continued operability requirements in respect of the UAS and sub-systems under consideration. The following may serve as guidelines for the engineering process. The UAS and sub-system qualification process is usually based on an appropriate engineering analysis, development and

	evaluation approach, of which the systems engineering approach is commonly used[31]. Different systems engineering definitions and models exist[31,32,33,34], and the USA Defence Acquisition University defines it as "a structured, disciplined, and documented technical effort that simultaneously designs and develops systems products and processes to satisfy the needs of the customer"[35]. In managing its systems engineering effort, the UAS Department of Defence applies eight technical management processes, including: - technical planning; - requirements management; - interface management; - risk management; - configuration management; - technical data management; - technical assessment; and - decision analysis[35,36,37]. The systems engineering process addresses engineering issues of a system/product throughout its life cycle and typically includes the following primary elements[30,36,37]: - stakeholders requirements definition:- technical specifications for the required system/product are defined; - requirements analysis:- the specifications are analysed and concept system/product sub-systems, components and enabling or critical technologies are defined; - system/product design:- feasibility studies are carried out and a final design is selected; - implementation:- all system/product sub-systems and components, including hardware and software, are manufactured, acquired or re-used; - integration:- the integration of all sub-systems and components into the required system/product; - verification:- demonstrate compliance with the system/product specifications to show that the system/product design, development and integration were done correctly; - validation:- confirm that the correct system/product was produced in response to the stakeholders requirements; and - transition:- the process to produce the system/product, and to deliver it to the stakeholders/users for operational use.

C-2.4.3 Section: Continued Compliance

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Criteria for Initial and Continued Compliance with Operability Requirements	Continued Compliance	Continued Compliance Process and Procedures

This section describes the procedures to ensure that continued compliance with the relevant operability requirements is maintained for the UAS and sub-systems under consideration. Continued compliance includes all activities that are required to ensure that the UAS and sub-systems are operated and maintained in compliance with:

- the original operability requirements against which initial compliance was achieved[25]; as well as
- newly defined operability requirements that may become applicable to the UAS as a result of operating changes, design changes, modifications, repairs, and changes in maintenance requirements.

The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
Continued Compliance Process and Procedures *<Continued Operability Entity>*	Although numerous examples exist in traditional aviation regulation[38,39,40,41], military aviation[21,22,23,42,43,,44], and in the reusable launch vehicle (RLV) domain[45] for continued airworthiness and flightworthiness processes and requirements, the intention of this sub-section is to describe the required procedures to ensure continued compliance with the relevant engineering and regulatory requirements. The continued compliance procedures developed under this sub-section should[45]: - ensure public safety and limit and/or mitigate potential environmental hazards; - identify the maintenance and logistical support strategies for the UAS and sub-systems under consideration; - ensure the implementation of an appropriate configuration management system for the UAS and sub-system hardware, software and documentation; and - include a program to investigate human errors and subsequently introduce procedures to minimise the potential for their recurrence. More specifically, the continued compliance process[29] for the UAS and sub-systems under consideration should include procedures for: - development and implementation of an appropriate maintenance program; - system and sub-system configuration management; - non-destructive testing (NDT) and inspections; - carrying out of maintenance in respect of servicing, repairs and modifications;

	- carrying out of maintenance, scheduled and unscheduled; - system and sub-system overhauls; - system and sub-system upgrades; - sub-system replacements; - management of maintenance records; - monitoring and incorporation of system and sub-system manufacturer service bulletins; - monitoring and incorporation of operability/airworthiness directives; - monitoring, investigating and resolving of errors, including human errors; and - compliance during phasing out/disposal processes, when required.

C-2.5 Sub-Part: Risk Management

This sub-part must contain general procedures associated with the risk management of the UAS and sub-systems under consideration. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Risk Management	Introduction	
		Risk Management Criteria	Hazard Identification; Risk Assessment; Risk Control Plan; Risk Acceptance; Risk Tracking

The operability criteria for the sections of this sub-part are given in the following paragraphs.

C-2.5.1 Section: Introduction

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Risk Management	Introduction	

This section describes the objectives and scope of this sub-part in respect of risk management criteria associated with the UAS and sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SECTION	OPERABILITY CRITERIA
Introduction	Assessing and managing the risks that are associated with the operability of the UAS and sub-systems under consideration, is necessary to ensure the safe and continued operation of the UAS[25]. Appropriate risk management procedures should therefore be established and implemented, whether the UAS is regulated or not. The procedures should incorporate at least the following principles[22]: - The risks associated with the operability of the UAS and sub-systems should be balanced against the operational impact and cost of the UAS. For most UAS operations, there is a higher level of risk attached to the UAS operations than to traditional aviation, and "safety at any cost" should not necessarily apply in all cases. - Operability risks should be recognised, evaluated and accepted/rejected at appropriate levels by appropriate authorities. Not all risks affect safety to the same extent and risks should therefore be managed in the relevant organisations/authorities by appropriately authorised personnel. - "Accept necessary risk/Do not accept unnecessary risk"[22]. UAS operability risks must be managed either through acceptance or rejection. Accepting unnecessary risks is counter-productive and feasible options are usually available to reduce the level of such a risk, when the level (severity) of the risk is known. Conversely, when the risk level is assessed as reasonable and justified, the risk could be accepted. - Monitor and Assess Risk Continuously. Assessment of UAS operability risks depends on the quality and quantity of available data. Monitoring the UAS and sub-systems from as early in its developmental and operational life as possible will enable the collecting and analysis of a constantly growing body of risk data. In turn, the results of analysing the risk data, including system safety analyses, failure mode, effects and criticality analyses (FMECA's), and compliance testing, will enable the refinement of the risk assessment and management process.

C-2.5.2 Section: Risk Management Criteria

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART II - PROCEDURAL CRITERIA			
	Risk Management	Risk Management Criteria	Hazard Identification; Risk Assessment; Risk Control Plan; Risk Acceptance; Risk Tracking

UAS operability risk management must be a continuous process to identify, assess and control the safety risks associated with the operability of the UAS and sub-systems under consideration. The process that should be applied to the UAS and sub-systems typically consists of five basic elements[22], including:

- hazard identification;
- risk assessment;
- risk control plan;
- risk acceptance; and
- risk tracking.

This section describes the criteria associated with these five basic risk management elements. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
Hazard Identification	A hazard is considered to be any actual or potential condition that can degrade the level of safety of a product and usually originates from a part failure, system performance degradation or environmental exposure under specific conditions. The hazard condition may result in one or more effects or consequences, such as death, injury, equipment damage, or environmental damage[22]. Procedures to identify hazards should be developed and implemented and should typically include[22]: - design reviews; - system safety programmes; - failure mode effect and criticality analyses; - safety/flight critical parts lists; - historical data from test programmes; - engineering report analyses; - system interface assessments; - quality deficiency reports; and - analysis of accident and incident reports for in-service UAS.
Risk Assessment	Quantitative and qualitative risk assessment methods exist to determine the severity of hazard conditions[22]. Although quantitative methods provide measurable results, the methods must usually be tailored for different situations and systems. Qualitative methods are easier to apply but their results are more susceptible to differences in interpretation. Procedures must be developed and implemented to identify risks in respect of the UAS and sub-systems under consideration as unacceptable risks

	or residual risks[22]. Unacceptable risks are the risks that should be mitigated, eliminated or reduced, whereas residual risks include acceptable risks and unidentified risks[22].
Risk Control Plan	A risk control plan in respect of the UAS and sub-systems under consideration should be developed and implemented to[22]: - eliminate previously identified hazard conditions; - reduce the risk severity by reducing or limiting its potential effects and/or by reducing the probability of its occurrence; and - mitigate the risk severity by addressing and compensating for all relevant safety concerns. Risk control measures that can be incorporated in the risk control plan include[22]: - designing for minimum risk; - implementing hazard control measures; - providing emergency procedures and emergency procedure training; - incorporating appropriate warning devices, safety devices or system redundancies; and - where personnel are involved (in non-airborne systems, for example), providing adequate emergency evacuation capabilities.
Risk Acceptance	The risk acceptance process in respect of the UAS and sub-systems under consideration must include procedures to ensure that the risk control plan is implemented effectively, that selected risk control measures are effective and accepted, that any resulting residual risks are acceptable, and that the residual risks are accepted in an accountable manner[22].
Risk Tracking	The process of managing UAS operability risks must be supported by a process in which the accepted residual risks associated with the UAS and sub-systems under consideration are continuously monitored during the operational service life of the UAS[22]. Changes in risk levels should be assessed in accordance with the risk management procedures and where a risk becomes unacceptable, appropriate engineering effort should be applied to mitigate, eliminate or reduce the risk.

C-3. UAS OPERABILITY FRAMEWORK PART III: UAS OPERABILITY CRITERIA

Part III of the UAS Operability Framework addresses the technical and engineering criteria and requirements for achieving and maintaining operability of the UAS and sub-systems under consideration.

As in Parts I and II of the framework, it must be recognised that not all criteria and requirements included in this Part will necessarily apply to the UAS and sub-systems under consideration and sound engineering judgement must be used to select, tailor and expand the appropriate criteria and requirements. Such judgement should be based on considerations of both the operability and the safe operation of the UAS.

The table below gives an overview of the scope of this part as included in the Framework for the purposes of this thesis.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART III - UAS OPERABILITY CRITERIA			
UAS OPERABILITY FRAMEWORK PART IIIA - SYSTEM OF SYSTEMS OPERABILITY CRITERIA			
	Introduction	Engineering Approach Criteria; Engineering Process Criteria	
	System Operability	Achieving Initial System-level Operability	Define Missions and System Requirements; Conceptualise System and Constituent Sub-Systems; Finalise System of Systems and Sub-system Designs; Integrate System of Systems Sub-systems; Test and Evaluate System of Systems; Acceptance of System of Systems; Confirm System of Systems Operability
		Maintaining Continued System-level Operability	Acceptance of System of Systems; Confirm System of Systems Operability; Monitor and Maintain System of Systems Continued Operability; Monitor and Maintain Sub-system Continued Operability; Confirm Post-maintenance System of Systems Operability; System of Systems Termination, Decommissioning and Disposal
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Introduction		
	General	Applicability	
		Operations and Missions of the UAS Airborne Sub-systems	
	Flight and Ground Handling	General	Verification and Validation; Aircraft Principles of Flight; Aircraft Weights; Centre of Gravity Range and Limits; Removable Ballast; Payload and Payload Distribution; Load Distribution Limits; Airborne Sub-systems other than the Aircraft
		Aircraft Performance	General; Minimum Flight Speed; Stall Speed; Take-off/Launch Performance; Climb Performance; Glide Performance; Landing/Recovery Performance; Cruise Performance; Manoeuvring Performance and Limitations; Loitering Performance; Combat Performance and Limitations; Maximum Speed; Endurance; Range; Performance of Airborne Sub-systems other than the Aircraft
		Flight Characteristics	General; Aircraft Aerodynamics; Aircraft Flight Characteristics; Flight Characteristics of Airborne Sub-systems other than the Aircraft
		Controllability and Manoeuvrability	General; Flight Control System; Minimum Control Speed; Trim
		Stability	Stability Characteristics
		Stalls	Stalls; Stall Protection
		Spinning	Spinning
		Surface Handling Characteristics	Surface Handling; Stability and Control; Operation from Unprepared Surfaces
		Miscellaneous Requirements	Vibration and Buffeting; High Speed Characteristics; Other Novel Characteristics
		Assisted Take-Off/Launch	Take-off/Launch Safety; Take-off/Launch System Interfacing; Take-off/Launch Performance; Transition to Normal Flight; Control of Aircraft During Take-off/Launch
		Assisted Landing/Recovery	Landing/Recovery Safety; Aircraft Performance before Landing/Recovery; Landing/Recovery System Interfacing; Control of Aircraft During Landing/Recovery
		Emergency Landing/Recovery	Emergency Landing/Recovery Safety; Emergency Landing/Recovery System Interfacing; Control of Aircraft during Emergency Landing/Recovery
	Flight and Surface Operation Load Considerations	Flight Loads	General; Flight Loads and Flight Load Considerations
		Control System Loads	General; Primary Control System Loads; Secondary Control System Loads; Limit Control Forces and Torques; Surface Gust Conditions
		Pitch Control Device Loads	General; Pitch Control Device Loads; Balancing Loads; Unsymmetrical Loads; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Yaw Control Device Loads	General; Yaw Control Device Loads; Balancing Loads; Unsymmetrical Loads; Outboard Fins and Winglets; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Roll Control Device Loads	General; Roll Control Device Loads; Balancing Loads; Unsymmetrical Loads; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Surface Operation Loads	General; Surface Operation Loads and Surface Operation Load Considerations
		Emergency Conditions	General
		Catapult Assisted and Rocket Assisted Take-Off Loads	Launch Loads; Trolley or Shuttle Loads; Rocket Assisted Take-off Loads
		Parachute Recovery System Loads	Parachute Recovery Loads; Extracting Devices; Sacrificial Elements; Aircraft Dragging on the Surface
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Flutter; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors
		Flight Management System	Flight Management System; Flight Safety System; Flight Control System; Autonomy; Health Monitors and Data Recorders
		Structures	Primary Structural Elements; Other Structural Elements; Flight Controls; Onboard Launch System Elements; Onboard Recovery System Elements
		Rotors	General
		Flight Control Devices	General; Surface Gust Conditions

		Control Systems	General
		Landing Gear	General
		Payload and Equipment Accommodations - Internal and External	Internal Compartments; External Equipment Installations; External Payload Hardpoints
		Pressurisation and Environmental Control Systems	Pressurised Compartments; Environmental Control Systems
		Fire Protection	General; Fire Extinguishing Systems
		Miscellaneous	Levelling Means; Ballast Provisions
		Floats and Hulls	General
		Emergency Systems	Emergency Recovery Systems; Flight Termination Systems
		Electrical Systems	General
		Software	General; Software Maintenance
		Navigation and Communication Systems	General
		Mechanical Systems	General
	Powerplant and Powerplant Installation	General	Powerplant Type; Rotor and Power Transmission Systems
		Powerplant Systems	General; Transmissions and Gearboxes
		Fuel Systems	General; In-flight Refuelling Systems
		Energy Storage Systems	General
		Powerplant Fire Protection	General
		Powerplant Controls and Accessories	Powerplant Controls; Powerplant Accessories
	Hazard and Collision Avoidance	Hazard Avoidance Systems	General
		Collision Avoidance Systems	General
	Avionics, Instruments and Equipment	General	Software; Software Maintenance
		Communication and Navigation Equipment	Communication Equipment; Command and Control Data Link; Navigation Equipment
		Instruments and Sensors	General
		Automatic Take-off and Landing Systems	General; Manual and Automatic Abort Functions
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Safety Equipment and Emergency Capabilities	Safety Equipment; Emergency Capabilities
		Miscellaneous Equipment	General
	Operating Limitations, Safety Information and System Manual	Operating Limitations	General
		Markings and Placards	General
		Aircraft/Airborne Sub-system Manual	General
	Continued Operability and Airworthiness	Continued Operability and Airworthiness Requirements	General
	Security	Aircraft/Airborne Sub-system Security	General
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Introduction		
	General	Applicability	
		Functions of Non-Airborne Sub-systems	
	Operating and Functional Characteristics	General	Verification and Validation
		Take-off/Launch System	General; Take-off/Launch System Safety
		Landing/Recovery System	General; Landing/Recovery System Safety; Emergency Landing/Recovery Safety
		Remote Control Station	General; Remote Control Station Safety
		Other Non-Airborne Support Systems	General; Support System Safety
	Load Considerations	Take-off/Launch System Loads	General
		Landing/Recovery System Loads	General
		Remote Control Station Loads	General
		Other Non-Airborne Support System Loads	General
		Emergency Conditions	General
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors; Transportability; Storage Provisions
		Structures	Primary Structural Elements; Other Structural Elements
		Controls and Equipment	General
		Internal Environment Control Systems	General
		Fire Protection	General; Fire Extinguishing Systems
		Environmental Hazards Protection	General
		Emergency Systems	General
		Electrical Systems	General
		Software	General; Software Maintenance
		Mechanical Systems	General
		Powerplants	General
	Instruments and Equipment	General	Software; Software Maintenance
		Communication Equipment	Communication Equipment; Command and Control Data Link
		Instruments and Sensors	General
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Safety Equipment and Emergency Capabilities	Safety Equipment
		Miscellaneous Equipment	General

	Operating Limitations, Safety Information and System Manuals	Operating Limitations	General
		Markings and Placards	General
		System Manuals	General
	Continued Operability	Continued Operability Requirements	General
	Security	Non-Airborne Sub-system Security	General
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Introduction		
	General	Applicability	
	General and Functional Characteristics	General	Verification and Validation
		Cargo Payloads	General; Payload Safety
		Functional Payloads	General; Payload Safety; Safety during UAS Emergency
	Load Considerations	Cargo Payloads	General
		Functional Payloads	General
		Emergency Conditions	General
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors; Transportability; Storage Provisions
		Structures	Primary Structural Elements; Other Structural Elements
		Controls and Equipment	General
		Fire Protection	General
		Environmental Hazards Protection	General
		Emergency Systems	General
		Electrical Systems	General
		Software	General; Software Maintenance
		Mechanical Systems	General
	Instruments and Equipment	General	Software; Software Maintenance
		Communication Equipment	Communication Equipment; Data Link
		Instruments and Sensors	General
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Miscellaneous Equipment	General
	Operating Limitations, Safety Information and System Manuals	Operating Limitations	General
		Markings and Placards	General
		System Manuals	General
	Continued Operability	Continued Operability Requirements	General
	Security	Payload Security	General

The criteria relevant to this part are presented in the following chapters.

C-4. UAS OPERABILITY FRAMEWORK PART IIIA: SYSTEM OF SYSTEMS OPERABILITY CRITERIA

Whereas a typical manned aircraft can usually be declared operable/airworthy as an independent entity, the operability of a UAS as a complete system is inter-dependent[4,26,46] on:

- the airworthiness of the airborne sub-system or sub-systems;
- the operability of the non-airborne sub-systems; and
- the operability of its payloads, when the payloads are not "dead cargo".

Each of these sub-systems must therefore not only be operable on their own, but they must also interface and be interoperable with the other sub-systems. The formation of a system with such interdependent sub-systems is known as a system of systems[47]. The typical UAS is a system of systems which in itself must interface and be interoperable with other systems in a 'family of systems'[47].

It is therefore necessary to recognise that the development of airborne sub-systems, non-airborne sub-systems and payloads should not be carried out in isolation[32], and that it is not sufficient to only achieve the airworthiness of the airborne sub-systems, the operability of the non-airborne sub-systems and the operability of relevant payloads of a UAS. It is also necessary that the operability of the UAS as a system of systems is achieved and maintained[32] to ensure that the UAS as an integrated system is functional and safe.

Although the typical UAS is presently developed, marketed and operated as an integrated system[2,3,4,12,13,15,16,17,43,48,49,50], the system of systems approach has not previously been used to address operability criteria in respect of such an integrated UAS. Therefore, based on the system of systems approach and applying systems engineering principles, this part describes criteria and requirements for achieving and maintaining the operability of the UAS and its sub-systems under consideration as an integrated system of systems.

The table below gives a summary overview of the operability criteria and requirements in the Framework for the purposes of this thesis.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIA - SYSTEM OF SYSTEMS OPERABILITY CRITERIA			
	Introduction	Engineering Approach Criteria; Engineering Process Criteria	
	System Operability	Achieving Initial System-level Operability	Define Missions and System Requirements; Conceptualise System and Constituent Sub-Systems; Finalise System of Systems and Sub-system Designs; Integrate System of Systems Sub-systems; Test and Evaluate System of Systems; Acceptance of System of Systems; Confirm System of Systems Operability
		Maintaining Continued System-level Operability	Acceptance of System of Systems; Confirm System of Systems Operability; Monitor and Maintain System of Systems Continued Operability; Monitor and Maintain Sub-system Continued Operability; Confirm Post-maintenance System of Systems Operability; System of Systems Termination, Decommissioning and Disposal

The criteria relevant to the sub-parts of this part are presented in the following paragraphs.

C-4.1 Sub-Part: Introduction

This sub-part must introduce the objectives and scope of the sub-part in respect of achieving and maintaining operability of the UAS under consideration as a system of systems. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIA - SYSTEM OF SYSTEMS OPERABILITY CRITERIA			
	Introduction	Engineering Approach Criteria; Engineering Process Criteria	

The operability criteria for the sections of this sub-part are given in the following paragraphs.

C-4.1.1 Section: Engineering Approach Criteria

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIA - SYSTEM OF SYSTEMS OPERABILITY CRITERIA			
	Introduction	Engineering Approach Criteria; Engineering Process Criteria	

This section must identify and describe the engineering approach that must be used to achieve and maintain system-level operability of the UAS under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS under consideration.

SECTION	OPERABILITY CRITERIA
Engineering Approach Criteria *<Continued Operability Entity>*	The engineering approach to be used to achieve and maintain the system-level operability must be described and should consider at least the following system-level aspects[32,51]: - identifying and defining the operability objectives and requirements; - identifying the constituent sub-systems of the system of systems and establishing their interfacing and interdependency characteristics; - developing a realistically feasible system of systems architecture to manage the development and refinement of the system over time[32]; - conceptualising and developing appropriate engineering solutions to satisfy the system of system objectives and requirements; - implementing the engineering solutions; - integrating, commissioning and monitoring the system of systems; - monitoring the sub-systems and incorporating the effects of sub-system changes in the system of systems; - ensuring an integrated approach to upgrades of the system of systems; and - ensuring the safe and effective decommissioning and/or disposal of the system of systems, or of its constituent sub-systems.

C-4.1.2 Section: Engineering Process Criteria

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIA - SYSTEM OF SYSTEMS OPERABILITY CRITERIA			
	Introduction	Engineering Approach Criteria; Engineering Process Criteria	

This section must identify and describe the engineering process that must be used to satisfy the defined engineering approach for the UAS under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS under consideration.

SECTION	OPERABILITY CRITERIA
Engineering Process Criteria *<Continued Operability Entity>*	To satisfy the engineering approach criteria in an accountable manner it is necessary to apply the defined engineering process, systems engineering or otherwise, to the UAS under consideration, with emphasis on the following primary steps[32]: - system requirements definition:- the development of the technical specifications for the UAS under consideration; - requirements analysis:- the UAS specifications are analysed and concept sub-systems, components and enabling or critical technologies are defined; - system of systems design:- feasibility studies are carried out and a final system of systems architecture/design is selected; - implementation:- all sub-systems and components, including hardware and software, of the system of systems are designed, developed and manufactured, or acquired, or re-used, as appropriate; - integration:- the integration of all sub-systems and components is done to produce the required system of systems; - verification:- compliance with the system of systems specifications is demonstrated to show that the system architecture/design, development and integration was done correctly; - validation: - the process of confirming that the correct system of systems was produced in response to the system requirements; and - transition:- the process to produce the system, and to deliver it to the stakeholders/users for operational use. As with systems engineering[35], these steps are typically managed by means of the following processes[30]: - technical planning; - requirements management; - interface management; - risk management; - configuration management; - technical data management; - technical assessment; and - decision analysis.

C-4.2 Sub-Part: System Operability

This sub-part must contain the relevant and appropriate operability criteria for the UAS under consideration. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIA - SYSTEM OF SYSTEMS OPERABILITY CRITERIA			
	System Operability	Achieving Initial System-level Operability	Define Missions and System Requirements; Conceptualise System and Constituent Sub-Systems; Finalise System of Systems and Sub-system Designs; Integrate System of Systems Sub-systems; Test and Evaluate System of Systems; Acceptance of System of Systems; Confirm System of Systems Operability
		Maintaining Continued System-level Operability	Acceptance of System of Systems; Confirm System of Systems Operability; Monitor and Maintain System of Systems Continued Operability; Monitor and Maintain Sub-system Continued Operability; Confirm Post-maintenance System of Systems Operability; System of Systems Termination, Decommissioning and Disposal

The operability criteria for the sections of this sub-part are given in the following paragraphs.

C-4.2.1 Section: Achieving Initial System-Level Operability

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIA - SYSTEM OF SYSTEMS OPERABILITY CRITERIA			
	System Operability	Achieving Initial System-level Operability	Define Missions and System Requirements; Conceptualise System and Constituent Sub-Systems; Finalise System of Systems and Sub-system Designs; Integrate System of Systems Sub-systems; Test and Evaluate System of Systems; Acceptance of System of Systems; Confirm System of Systems Operability

This section must identify and describe the engineering requirements that must be satisfied to achieve initial system-level operability of the UAS under consideration. These requirements are not only those described in the UAS user specification, but should also include all aspects that affect the system-level operability of the UAS, as derived from a structured engineering analysis during the systems engineering processes[32,51]. Since operability criteria for a UAS as a system of systems have not been defined previously, the following criteria were developed for UAS from similar criteria applied by NASA for achieving launch and flight readiness of space vehicles[32,51]. The criteria listed in the tables below should be tailored and expanded as appropriate for the respective UAS under consideration.

Sub-Section: Define Missions and System Requirements

SUB-SECTION	OPERABILITY CRITERIA
Define Missions and System Requirements	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Define and document mission, performance and safety requirements. - Identify major risks and define mitigation strategies. - Define requirements associated with decommissioning and disposal. - Place defined system requirements under change control. - Document and control traceability of system requirements to individual projects. - Define approach for verifying and validating compliance with system requirements. - Describe acceptance criteria for concept system of systems.

Sub-Section: Conceptualise System and Constituent Sub-Systems

SUB-SECTION	OPERABILITY CRITERIA
Conceptualise System and Constituent Sub-Systems	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Identify operational limits. - Define major constraints affecting system, such as cost, operating domains (ground, airspace, air traffic), required airborne sub-system characteristics, mission environment, international partners, technology drivers, and regulatory regimes. - Describe technical approach in respect of the system, including its constituent airborne, non-airborne and payload sub-systems, its operations and its logistics. - Define system architecture. - Identify and describe new systems to be developed (hardware and software), legacy systems, system interfaces, and facilities. - Compile and approve product design-to specifications for each hardware and software configuration item. - Update risk assessment and revise mitigation strategies. - Confirm system concept acceptance criteria are satisfied and procedures are in place to ensure closure of "open items". - Conceptualise final system of systems acceptance criteria. - Describe system of systems and constituent sub-system design acceptance criteria.

Sub-Section: Finalise System of Systems and Sub-System Designs

SUB-SECTION	OPERABILITY CRITERIA
Finalise System of Systems and Sub-System Designs *<Continued Operability Entity>*	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Update baseline design documents. - Confirm configuration of system, including all interfaces, is defined and under configuration control. - Confirm interfaces to other programs and stakeholders/partners are defined and under control. - Define and document system and system software functionalities. - Identify system safety critical characteristics and define associated requirements and procedures. - Complete and approve system technical data package. System data package should include: -- specifications; -- system risk assessment; -- system hazard and safety analyses; -- system failure modes and effects analysis; -- engineering analyses; -- reliability, availability and maintainability analyses; -- software design and software interface design documents; -- interface control documents; -- integrated logistics support documentation, including continued operability requirements; -- operability and/or airworthiness certifications for sub-systems; -- type certifications (where applicable); and -- operations documentation, including sub-system assembly and disassembly procedures. - Update risk assessment and mitigation strategies, and confirm risks are effectively managed. - Confirm detailed designs meet the system requirements with an acceptable level of risk. - Compile and approve product build-to specifications for each hardware and software configuration item. - Define and approve system manufacturing, assembly, integration, and test plans and procedures. - Define handling, transportation and safety requirements and instructions. - Compile and approve system test and evaluation plans. - Compile and approve system verification and validation plans. - Compile and approve system termination, decommissioning and/or disposal plans. Plans must provide for required facilities, safety, environmental protection, crash site clearance and restoration, archival of system data, and trading of system assets (hardware, software and facilities), as appropriate. - Confirm system and constituent sub-system design acceptance criteria are satisfied and procedures are in place to ensure closure of "open items". - Review and update system acceptance criteria. - Describe system integration acceptance criteria.

Sub-Section: Integrate System of Systems Sub-systems

SUB-SECTION	OPERABILITY CRITERIA
Integrate System of Systems Sub-systems	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Define and document integration process and procedures. - Confirm test results for sub-systems integration. - Integrate sub-systems and approve integration. - Demonstrate required integration facilities such as infrastructure, ground support equipment, handling equipment and machinery, and test equipment, to be appropriate and effective. - Verify all interfaces against interface control documentation. - Update and approve system integrated logistics support documentation. - Update and approve system operations documentation. - Update risk assessment and mitigation strategies, and confirm risks are effectively managed. - Confirm system integration acceptance criteria are satisfied and procedures are in place to ensure closure of "open items". - Review and update system acceptance criteria. - Describe system of systems test and evaluation acceptance criteria.

Sub-Section: Test and Evaluate System of Systems

SUB-SECTION	OPERABILITY CRITERIA
Test and Evaluate System of Systems *<Continued Operability Entity>*	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Define and document system test and evaluation objectives clearly. - Define and approve test plans, procedures, environment and equipment and confirm these are appropriate and sufficient for the system under test. - Confirm all functional tests, and sub-system and system verification, validation and regulatory certification tests had been carried out successfully. - Confirm system software functionality successfully tested, verified and demonstrated. - Confirm system interfaces (internal and external) tested and demonstrated to meet system integrity and operability requirements. - Confirm system-related test failures resolved and results documented and incorporated into system. - Demonstrate and confirm that system test and evaluation objectives have been achieved. - Identify and describe all operational test resources, including facilities, test specimens, equipment, instrumentation, personnel, test and evaluation procedures and any other resources necessary to conduct system-level tests and evaluations during the system's operational life. - Review system safety critical characteristics and update associated requirements and procedures. - Update system technical data package with test results and resulting system changes. - Verify and validate system against requirements. - Confirm system test and evaluation acceptance criteria are satisfied and procedures are in place to ensure closure of "open items". - Review and confirm system acceptance criteria.

Sub-Section: Acceptance of System of Systems

SUB-SECTION	OPERABILITY CRITERIA
Acceptance of System of Systems *<Continued Operability Entity>*	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Confirm system safety critical characteristics and update and document associated requirements and procedures. - Review and update system termination, decommissioning and/or disposal plans. - Confirm all sub-systems are integrated and tested, and system demonstrated to be operable. - Confirm all system software elements are sufficiently mature and capable to support operations. - Update and complete system technical data package. - Confirm all open system and sub-system safety and risk items had been addressed appropriately to ensure maximum safety and minimum risk. - Confirm system-level risks and risk levels had been identified and accepted, and are under risk management. - Review and update system documentation to accurately reflect the characteristics and capabilities of the system to be accepted. - Confirm compliance with applicable regulatory requirements, and confirm this compliance is supported by relevant approvals and certifications. - Verify system to comply with requirements. - Validate system against requirements. - Confirm system acceptance criteria are satisfied. - Approve and declare system to be operable in a final system operability report.

Sub-Section: Confirm System of Systems Operability

SUB-SECTION	OPERABILITY CRITERIA
Confirm System of Systems Operability	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Confirm system acceptance criteria are satisfied and system was accepted. - Confirm system was declared operable in final system operability report. - Confirm the system and sub-systems are properly configured for operations. - Confirm that system safety and the system state support an operational "go" decision based on appropriate "go/no-go" criteria. - Confirm current system characteristics and capabilities. - Identify and acknowledge system operational limits and constraints. - Confirm airborne sub-systems and payloads are ready and authorised for flight. - Confirm non-airborne sub-systems are ready and authorised for flight support operations. - Confirm system interfaces (internal and external) had been checked and are functional. - Review system safety critical characteristics and activate associated requirements and procedures. - Confirm system operational readiness is approved, authorised and recorded.

C-4.2.2 Section: Maintaining Continued System-Level Operability

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIA - SYSTEM OF SYSTEMS OPERABILITY CRITERIA			
	System Operability	Maintaining Continued System-level Operability	Acceptance of System of Systems; Confirm System of Systems Operability; Monitor and Maintain System of Systems Continued Operability; Monitor and Maintain Sub-system Continued Operability; Confirm Post-maintenance System of Systems Operability; System of Systems Termination, Decommissioning and Disposal

This section must identify and describe the engineering requirements that must be satisfied to maintain continued system-level operability of the UAS under consideration. These requirements should include all aspects that affect the continued system-level operability of the UAS, and are derived from the UAS and sub-system development and integration process. Since continued operability criteria for a UAS as a system of systems have not been defined previously, the following criteria were developed for UAS from similar criteria applied by NASA and the FAA for space vehicles[51], re-useable launch vehicles (RLVs)[52] and manned aircraft[39]. The criteria listed in the tables below should be tailored and expanded as appropriate for the respective UAS under consideration.

Sub-Section: Acceptance of System of Systems

SUB-SECTION	OPERABILITY CRITERIA
Acceptance of System of Systems <*Continued Operability Entity*>	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Confirm all sub-systems are integrated, tested and operable. - Confirm system technical data package is updated and complete. - Confirm all open system and sub-system safety and risk items had been addressed. - Confirm system-level risks and risk levels had been accepted and are under risk management. - Confirm system documentation accurately reflects the characteristics and capabilities of the system. - Confirm compliance with applicable regulatory requirements, and confirm relevant approvals and certifications support this compliance. - Confirm system is approved, accepted and declared operable.

Sub-Section: Confirm System of Systems Operability

SUB-SECTION	OPERABILITY CRITERIA
Confirm System of Systems Operability *<Continued Operability Entity>*	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Confirm current system characteristics and capabilities and confirm these are adequate for planned operations. - Confirm system and sub-systems are configured for planned operations. - Confirm relevant system and sub-system equipment and instrumentation are calibrated for planned operations. - Confirm system operational limits and constraints are identified and acknowledged. - Confirm airborne sub-systems and payloads are ready and authorised for flight. - Confirm non-airborne sub-systems are ready and authorised for flight support operations. - Confirm system interfaces (internal and external) are checked and functional. - Confirm system safety critical characteristics had been reviewed and associated requirements and procedures had been activated. - Confirm system safety and confirm the system state supports an operational "go" decision based on appropriate "go/no-go" criteria. - Confirm system operability approved, authorised and recorded.

Sub-Section: Monitor and Maintain System of Systems Continued Operability

SUB-SECTION	OPERABILITY CRITERIA
Monitor and Maintain System of Systems Continued Operability *<Continued Operability Entity>*	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Maintain system operability status through rigorous monitoring and control of system and sub-system continued operability programmes. - Compile and implement system-level maintenance, inspection and overhaul procedures based on sub-system procedures, regulatory requirements and system manufacturer's data. - Monitor system continued operability status, including operability of external sub-systems such as communications and data networks, third-party service providers, etc. - Maintain operability at system-level in accordance with: -- mandatory inspection times; -- mandatory overhaul and replacement times; -- approved inspection procedures for mandatory inspections; and -- required maintenance tasks to detect and correct safety and operability-related failures at system-level, not normally known to operating crews (latent failures). - Identify requirements for significant changes to the system, system interfaces, and system operating procedures and ensure requirements are addressed satisfactorily. - Document system operations anomalies, assess their impact on operations and resolve them appropriately. - Record system operations problems and ensure appropriate corrective actions are implemented. - Ensure system operability status is updated when changes occur at sub-system level. - Record and retain relevant system data for system trends and system "lessons learned".

Sub-Section: Monitor and Maintain Sub-System Continued Operability

SUB-SECTION	OPERABILITY CRITERIA
Monitor and Maintain Sub-System Continued Operability *<Continued Operability Entity>*	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Maintain sub-system operability status through rigorous monitoring and control of sub-system continued operability programmes. - Sub-system maintenance, inspection, modification, repair and overhaul procedures based on criteria in Parts IIIB, C and D of this operability requirements framework, regulatory requirements and manufacturers' data. - Maintain sub-systems in accordance with approved manufacturers' data. - Identify requirements for significant changes to sub-systems, interfaces, and sub-system operating procedures and ensure requirements are addressed satisfactorily. - Document sub-system operations anomalies, assess their impact on operations and resolve them appropriately. - Record sub-system operations problems and ensure appropriate corrective actions are implemented. - Ensure changes to sub-systems are communicated to system-level and system operability status is updated accordingly. - Record and retain relevant sub-system data for sub-system trends and "lessons learned".

Sub-Section: Confirm Post-Maintenance System of Systems Operability

SUB-SECTION	OPERABILITY CRITERIA
Confirm Post-Maintenance System of Systems Operability *<Continued Operability Entity>*	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Confirm all sub-systems that had been subjected to inspections, maintenance, repair, modification, overhaul/upgrade or replacement had been tested and were declared operable. - Confirm all sub-systems had been integrated and tested, and system had been declared operable. - Confirm system and sub-system maintenance documentation is updated and complete. - Confirm system and sub-system technical data packages are updated and complete. - Confirm all open system and sub-system safety and risk items had been addressed. - Confirm system-level risks and risk levels had been accepted and are under risk management. - Confirm sub-system documentation accurately reflects the characteristics and capabilities of the relevant sub-systems. - Confirm system documentation accurately reflects the characteristics and capabilities of the system of systems. - Confirm compliance with applicable regulatory requirements and confirm relevant approvals and certifications support this compliance. - Confirm system is approved, accepted and declared operable.

Sub-Section: System of Systems Termination, Decommissioning and Disposal

SUB-SECTION	OPERABILITY CRITERIA
System of Systems Termination, Decommissioning and Disposal *<Continued Operability Entity>*	For the UAS and sub-systems under consideration, procedures must be developed to implement the following system of systems operability criteria: - Review and update system termination, decommissioning and/or disposal plans. - Confirm required facilities, equipment and services are provided and ready for use. - Confirm safety and environmental protection measures are established and ready for commissioning. - Confirm system data had been archived and archives are under control. - Terminated systems: Confirm crash site clearance and restoration procedures and preparations are in place, as required and applicable. - Decommissioned systems: Confirm trading of system assets (hardware, software and facilities) is approved, authorised and in compliance with relevant national and international laws. Confirm storing, including "moth-balling", of systems and sub-systems is carried out in accordance with manufacturers' instructions. - Decommissioned systems and systems/sub-systems to be disposed of: Confirm disposal procedures, facilities, equipment and safety measures are in place and ready for commissioning. Confirm disposal is carried out in accordance with manufacturers' instructions and regulatory requirements.

C-5. UAS OPERABILITY FRAMEWORK PART IIIB: AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA

This part provides general information and technical details of the UAS airborne sub-systems under consideration. Although the airborne sub-system of the UAS is usually considered to be the aircraft, it must be recognised that the aircraft may not be the only airborne sub-system that forms part of the UAS. Other airborne sub-systems may include chase aircraft, airborne communications relay aircraft/devices, airborne launch and/or recovery devices, satellite systems, and any other airborne sub-systems that are considered to be system sub-systems of the UAS. This part should therefore be used to address all such airborne sub-systems and should be tailored and expanded as appropriate for the respective UAS airborne sub-systems. The table below gives a summary overview of the operability requirements and criteria included in the Framework for the purposes of this thesis.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Introduction		
	General	Applicability	
		Operations and Missions of the UAS Airborne Sub-systems	
	Flight and Ground Handling	General	Verification and Validation; Aircraft Principles of Flight; Aircraft Weights; Centre of Gravity Range and Limits; Removable Ballast; Payload and Payload Distribution; Load Distribution Limits; Airborne Sub-systems other than the Aircraft
		Aircraft Performance	General; Minimum Flight Speed; Stall Speed; Take-off/Launch Performance; Climb Performance; Glide Performance; Landing/Recovery Performance; Cruise Performance; Manoeuvring Performance and Limitations; Loitering Performance; Combat Performance and Limitations; Maximum Speed; Endurance; Range; Performance of Airborne Sub-systems other than the Aircraft
		Flight Characteristics	General; Aircraft Aerodynamics; Aircraft Flight Characteristics; Flight Characteristics of Airborne Sub-systems other than the Aircraft
		Controllability and Manoeuvrability	General; Flight Control System; Minimum Control Speed; Trim
		Stability	Stability Characteristics
		Stalls	Stalls; Stall Protection
		Spinning	Spinning
		Surface Handling Characteristics	Surface Handling; Stability and Control; Operation from Unprepared Surfaces
		Miscellaneous Requirements	Vibration and Buffeting; High Speed Characteristics; Other Novel Characteristics
		Assisted Take-Off/Launch	Take-off/Launch Safety; Take-off/Launch System Interfacing; Take-off/Launch Performance; Transition to Normal Flight; Control of Aircraft During Take-off/Launch
		Assisted Landing/Recovery	Landing/Recovery Safety; Aircraft Performance before Landing/Recovery; Landing/Recovery System Interfacing; Control of Aircraft During Landing/Recovery
		Emergency Landing/Recovery	Emergency Landing/Recovery Safety; Emergency Landing/Recovery System Interfacing; Control of Aircraft during Emergency Landing/Recovery
	Flight and Surface Operation Load Considerations	Flight Loads	General; Flight Loads and Flight Load Considerations
		Control System Loads	General; Primary Control System Loads; Secondary Control System Loads; Limit Control Forces and Torques; Surface Gust Conditions
		Pitch Control Device Loads	General; Pitch Control Device Loads; Balancing Loads; Unsymmetrical Loads; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Yaw Control Device Loads	General; Yaw Control Device Loads; Balancing Loads; Unsymmetrical Loads; Outboard Fins and Winglets; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Roll Control Device Loads	General; Roll Control Device Loads; Balancing Loads; Unsymmetrical Loads; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Surface Operation Loads	General; Surface Operation Loads and Surface Operation Load Considerations

		Emergency Conditions	General
		Catapult Assisted and Rocket Assisted Take-Off Loads	Launch Loads; Trolley or Shuttle Loads; Rocket Assisted Take-off Loads
		Parachute Recovery System Loads	Parachute Recovery Loads; Extracting Devices; Sacrificial Elements; Aircraft Dragging on the Surface
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Flutter; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors
		Flight Management System	Flight Management System; Flight Safety System; Flight Control System; Autonomy; Health Monitors and Data Recorders
		Structures	Primary Structural Elements; Other Structural Elements; Flight Controls; Onboard Launch System Elements; Onboard Recovery System Elements
		Rotors	General
		Flight Control Devices	General; Surface Gust Conditions
		Control Systems	General
		Landing Gear	General
		Payload and Equipment Accommodations - Internal and External	Internal Compartments; External Equipment Installations; External Payload Hardpoints
		Pressurisation and Environmental Control Systems	Pressurised Compartments; Environmental Control Systems
		Fire Protection	General; Fire Extinguishing Systems
		Miscellaneous	Levelling Means; Ballast Provisions
		Floats and Hulls	General
		Emergency Systems	Emergency Recovery Systems; Flight Termination Systems
		Electrical Systems	General
		Software	General; Software Maintenance
		Navigation and Communication Systems	General
		Mechanical Systems	General
	Powerplant and Powerplant Installation	General	Powerplant Type; Rotor and Power Transmission Systems
		Powerplant Systems	General; Transmissions and Gearboxes
		Fuel Systems	General; In-flight Refuelling Systems
		Energy Storage Systems	General
		Powerplant Fire Protection	General
		Powerplant Controls and Accessories	Powerplant Controls; Powerplant Accessories
	Hazard and Collision Avoidance	Hazard Avoidance Systems	General
		Collision Avoidance Systems	General
	Avionics, Instruments and Equipment	General	Software; Software Maintenance
		Communication and Navigation Equipment	Communication Equipment; Command and Control Data Link; Navigation Equipment
		Instruments and Sensors	General
		Automatic Take-off and Landing Systems	General; Manual and Automatic Abort Functions
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Safety Equipment and Emergency Capabilities	Safety Equipment; Emergency Capabilities
		Miscellaneous Equipment	General
	Operating Limitations, Safety Information and System Manual	Operating Limitations	General
		Markings and Placards	General
		Aircraft/Airborne Sub-system Manual	General
	Continued Operability and Airworthiness	Continued Operability and Airworthiness Requirements	General
	Security	Aircraft/Airborne Sub-system Security	General

The criteria relevant to the sub-parts of this part are presented in the following paragraphs.

C-5.1 Sub-Part: Introduction

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Introduction		

This sub-part must introduce the part, describe its purpose and scope in respect of the UAS airborne sub-systems under consideration, and give a high-level overview of the airborne sub-systems of the respective UAS. The detail required in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-PART	OPERABILITY CRITERIA
Introduction	Introduce this part and describe its purpose and scope.

C-5.2 Sub-Part: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	General	Applicability; Operations and Missions of the UAS Airborne Sub-systems	

This sub-part must define the applicability of the UAS airborne sub-systems under consideration and must describe the operations and missions for which the particular airborne sub-systems can be utilised. The criteria listed in the table below should be tailored and expanded as appropriate.

SECTION	OPERABILITY CRITERIA
Applicability	Define and describe the respective UAS airborne sub-systems, including variants and derivatives, to which this section applies.
Operations and Missions of the UAS Airborne Sub-systems	Define and describe the scope of operations and missions that are contemplated for the respective UAS airborne sub-systems under consideration.

C-5.3 Sub-Part: Flight and Ground Handling

This sub-part must contain the relevant and appropriate operability criteria for the UAS airborne sub-systems under consideration that will ensure the effective and safe functioning of the airborne sub-systems in flight and on the surface. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Ground Handling	General	Verification and Validation; Aircraft Principles of Flight; Aircraft Weights; Centre of Gravity Range and Limits; Removable Ballast; Payload and Payload Distribution; Load Distribution Limits; Airborne Sub-systems other than the Aircraft
		Aircraft Performance	General; Minimum Flight Speed; Stall Speed; Take-off/Launch Performance; Climb Performance; Glide Performance; Landing/Recovery Performance; Cruise Performance; Manoeuvring Performance and Limitations; Loitering Performance; Combat Performance and Limitations; Maximum Speed; Endurance; Range; Performance of Airborne Sub-systems other than the Aircraft
		Flight Characteristics	General; Aircraft Aerodynamics; Aircraft Flight Characteristics; Flight Characteristics of Airborne Sub-systems other than the Aircraft
		Controllability and Manoeuvrability	General; Flight Control System; Minimum Control Speed; Trim
		Stability	Stability Characteristics
		Stalls	Stalls; Stall Protection
		Spinning	Spinning
		Surface Handling Characteristics	Surface Handling; Stability and Control; Operation from Unprepared Surfaces
		Miscellaneous Requirements	Vibration and Buffeting; High Speed Characteristics; Other Novel Characteristics
		Assisted Take-Off/Launch	Take-off/Launch Safety ; Take-off/Launch System Interfacing; Take-off/Launch Performance; Transition to Normal Flight; Control of Aircraft During Take-off/Launch
		Assisted Landing/Recovery	Landing/Recovery Safety ; Aircraft Performance before Landing/Recovery; Landing/Recovery System Interfacing; Control of Aircraft During Landing/Recovery
		Emergency Landing/Recovery	Emergency Landing/Recovery Safety; Emergency Landing/Recovery System Interfacing; Control of Aircraft during Emergency Landing/Recovery

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-5.3.1 Section: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Ground Handling	General	Verification and Validation; Aircraft Principles of Flight; Aircraft Weights; Centre of Gravity Range and Limits; Removable Ballast; Payload and Payload Distribution; Load Distribution Limits; Airborne Sub-systems other than the Aircraft

This section provides general information and technical details of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Verification and Validation	Conformance to specifications must be verified - all airborne sub-systems. Compliance with requirements must be validated - all airborne sub-systems.
Aircraft Principles of Flight[25]	Describe the principles of flight employed for the aircraft (fixed wing, rotary wing, balloon, airship, powered wing, etc).
Aircraft Weights[17]	Define the aircraft weight limits - empty, all-up, maximum take-off, maximum landing, payload weight limits, fuel weight limits.
Centre of Gravity Range and Limits[17]	Define the aircraft centre of gravity range and limits.
Removable Ballast[17]	Specify details, limitations and precautions of removable ballast applicable to the aircraft.
Payload and Payload Distribution	Define the aircraft payloads in terms of types (external/internal, active/non-active), aerodynamic profiles (external payloads), weights, dimensions, functionality (active payloads), required interfaces and required resources (electricity, data, hard points, etc).
Load Distribution Limits[17]	Define the aircraft load distribution options, configurations and limits.
Airborne Sub-systems other than the Aircraft	When applicable, define and describe airborne sub-systems of the UAS other than the aircraft, including sub-systems used on chase aircraft, airborne communications relay sub-systems, aerial re-fuelling sub-systems and and/or any other airborne sub-system that is considered an integral part of the UAS.

C-5.3.2 Section: Aircraft Performance

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Ground Handling	Aircraft Performance	General; Minimum Flight Speed; Stall Speed; Take-off/Launch Performance; Climb Performance; Glide Performance; Landing/Recovery Performance; Cruise Performance; Manoeuvring Performance and Limitations; Loitering Performance; Combat Performance and Limitations; Maximum Speed; Endurance; Range; Performance of Airborne Sub-systems other than the Aircraft

This section provides information and details of the flight performance of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General	Provide a general overview of the flight performance details of the aircraft, and when applicable, of any other airborne sub-system of the UAS.
Minimum Flight Speed[17]	List the minimum, controllable flying speed of the aircraft for each contemplated aircraft configuration.
Stall Speed[17]	List the stalling speed of the aircraft for each applicable aircraft configuration.
Take-off[17]/Launch Performance	Provide details of the take-off and/or launch performance of the aircraft in respect of speeds, distances, 'go-no go' launch criteria, and any other criteria that are critical for safe and effective take-offs/launches.
Climb Performance[17]	Provide details of the climb performance of the aircraft for contemplated configurations.
Glide Performance[17]	Provide details of the glide performance of the aircraft for contemplated configurations.
Landing[17]/Recovery Performance	Provide details of the landing and/or recovery performance of the aircraft in terms of speeds, distances, 'go-no go' recovery criteria, and any other criteria that are critical for safe and effective landings/recoveries.
Cruise Performance	Provide details of the cruise performance of the aircraft for contemplated configurations.
Manoeuvring Performance and Limitations	Provide details of the manoeuvring performance of the aircraft for contemplated configurations, including manoeuvring limitations in terms of structural strength and manoeuvrability.
Loitering Performance	Provide details of the loitering performance of the aircraft in terms of mission profiles, speeds, maximum loitering times, and loitering time limiting factors.
Combat Performance and Limitations	When applicable, provide details of the combat performance of the aircraft for contemplated configurations, including limitations in terms of structural strength, manoeuvrability and munition delivery profiles.
Maximum Speed	Provide details of the maximum level and never exceed speeds of the aircraft for contemplated configurations.
Endurance	Provide details of the endurance of the aircraft for contemplated configurations.
Range	Provide details of the range of the aircraft for contemplated configurations.

Performance of Airborne Sub-systems other than the Aircraft	When applicable and relevant, define and describe the performance of airborne sub-systems that are considered integral parts of the UAS, other than the aircraft.

C-5.3.3 Section: Flight Characteristics

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Ground Handling	Flight Characteristics	General; Aircraft Aerodynamics; Aircraft Flight Characteristics; Flight Characteristics of Airborne Sub-systems other than the Aircraft

This section provides information and details of the flight characteristics of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17]	Provide a general overview of the flight characteristics of the aircraft, particularly in the case of unique or novel designs, and when applicable, also of any other airborne sub-system of the UAS.
Aircraft Aerodynamics[25]	Describe the aircraft aerodynamic characteristics for each contemplated aircraft configuration.
Aircraft Flight Characteristics[53]	Describe the aircraft flight characteristics for each applicable aircraft configuration, including characteristics such as controllability, manoeuvrability, flight controls, static and dynamic stability, ground resonance[53] and any other characteristics that result from unique or novel designs.
Flight Characteristics of Airborne Sub-systems other than the Aircraft	When applicable and relevant, define and describe the flight characteristics of airborne sub-systems that are considered integral parts of the UAS, other than the aircraft.

C-5.3.4 Section: Controllability and Manoeuvrability

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Ground Handling	Controllability and Manoeuvrability	General; Flight Control System; Minimum Control Speed; Trim

This section provides information and details of the controllability and manoeuvrability of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17]	Provide a general overview of the controllability and manoeuvrability characteristics of the aircraft, particularly in the case of unique or novel designs, and when applicable, also of any other airborne sub-system of the UAS.
Flight Control System[25]	Describe the aircraft flight control system in respect of its architecture, functioning, performance, interfaces, and any other criteria that are critical for the safe and effective control and manoeuvring of the aircraft.
Controllability - The aircraft should be demonstrated to be controllable in all phases of anticipated flight, whether remotely piloted, optionally piloted, and/or under semi- or full autonomous control. Unsafe characteristics or control attributes that may impair the performance and/or functioning of the aircraft should be eliminated or appropriately mitigated.	Describe the control characteristics for each applicable aircraft configuration, and define the controllability limits of the aircraft and any required provisions, precautions and preparations for dealing with situations of control failure.
Manoeuvrability - The anticipated manoeuvrability of the aircraft must be demonstrated to be achievable and controllable for each aircraft configuration.	The manoeuvrability of the aircraft must be described and its manoeuvrability limits must be defined.
Trim[17] - As part of the control architecture of the aircraft flight control system, aircraft trim must be incorporated as a critical function that must be performed automaticically[17].	The trim functions included in the flight control system of the aircraft must be described and their limits must be defined.
Controllability and Manoeuvrability of Airborne Sub-systems other than the Aircraft	When applicable and relevant, define and describe the controllability and manoeuvrability of airborne sub-systems that are considered integral parts of the UAS, other than the aircraft.

C-5.3.5 Section: Stability

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Ground Handling	Stability	Stability Characteristics

This section provides information and details of the stability of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Stability Characteristics[17] - Unsafe stability characteristics or attributes that may impair the stability performance of the aircraft should be eliminated or appropriately mitigated.	Describe the stability characteristics of the aircraft, particularly in the case of unique or novel designs, and when applicable, also of any other airborne sub-system of the UAS.

C-5.3.6 Section: Stalls

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Ground Handling	Stalls	Stalls; Stall Protection

This section provides information and details of the stalling and stall protection characteristics of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Stalls[17] - When applicable, the stall performance of the aircraft must be demonstrated for all anticipated aircraft configurations. The stall demonstration must be performed with wings level, for turning flight, for accelerated turns and for any other flight manoeuvre that may result in a stall condition. Any stall conditions that may impair the performance and/or functioning of the aircraft should be eliminated or appropriately mitigated.	When applicable, describe the stall and stall recovery characteristics for each anticipated configuration of the aircraft, and in particular for unique or novel designs. These characteristics must at least be described for wings level stalls, turning flight stalls, accelerated turn stalls, and for any other flight manoeuvre that may result in a stall condition.
Stall Protection[17] - When required, the stall protection function must be incorporated into the flight control system[17] and must be demonstrated for all applicable aircraft configurations. No unsafe conditions may occur.	Describe the stall protection function and its characteristics, and define any limitations, maintenance, tests and precautions for ensuring its continued proper functioning.

C-5.3.7 Section: Spinning

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Ground Handling	Spinning	Spinning

This section provides information and details of the spin characteristics of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Spinning[17] - Although it is generally recommended that unmanned aircraft should be designed not to be capable of spinning, specific applications may require spinning abilities. When applicable therefore, the spinning performance, characteristics and spin recovery ability of the aircraft must be demonstrated for all aircraft configurations for which spinning will be utilised. Any spinning conditions that may impair the performance and/or functioning of the aircraft should be eliminated or appropriately mitigated.	When applicable, describe the spinning performance, characteristics and spin recovery procedures, limitations and precautions for each anticipated configuration of the aircraft, and in particular for unique or novel designs.

C-5.3.8 Section: Surface Handling Characteristics

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Handling	Surface Handling Characteristics	Surface Handling; Stability and Control; Operation from Unprepared Surfaces

This section provides information and details of the surface handling characteristics of the UAS airborne sub-systems under consideration. Surfaces to be considered in this section should include all surfaces on which the airborne sub-systems will need to operate, including ground[17], water, snow, ship decks and other prepared and unprepared surfaces. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Surface Handling	Describe the ground[17] and surface handling procedures, characteristics, limitations and precautions for each relevant configuration of the aircraft, and in particular for unique or novel designs. The ground and surface handling includes preparations for, and procedures during take-off, assisted take-off or launch, and preparations for, and procedures during and after landing, assisted landing, or aircraft recovery.
Stability and Control[17]	Describe the stability and control of the aircraft on the relevant surfaces on which it is anticipated the aircraft will operate, including stability and control limits and precautions.
Operation from Unprepared Surfaces[17]	When operation from unprepared surfaces is contemplated, the relevant handling procedures, characteristics, limitations and precautions for each applicable aircraft configuration and for the anticipated types of unprepared surfaces, must be described.

C-5.3.9 Section: Miscellaneous Flight Requirements

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Handling	Miscellaneous Requirements	Vibration and Buffeting; High Speed Characteristics; Other Novel Characteristics

This section provides information and details of those flight and surface handling characteristics of the UAS airborne sub-systems under consideration that are not described elsewhere in the framework. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Vibration and Buffeting[17] - UAS airborne sub-systems should be designed to be as free of excessive vibration and buffeting as is reasonably practicable and as will not cause structural damage or interference with the control and manoeuvring of the airborne sub-systems.	Describe known vibration and buffeting characteristics of the UAS airborne sub-systems, as well as precautions and limitations to prevent excessive vibrations and buffeting.
High[17] and Low Speed Characteristics	Describe any high and low speed regimes of the UAS airborne sub-systems that may result in loss of control, or damage or loss of the airborne sub-systems, and describe procedures, precautions and limitations to avoid such regimes. Describe recovery and/or emergency procedures for instances when such regimes are entered.
Other Novel Characteristics	Describe novel UAS airborne sub-system characteristics, handling procedures, precautions and limits that are not described elsewhere in the framework.

C-5.3.10 Section: Assisted Take-Off/Launch

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Handling	Assisted Take-Off/Launch	Take-off/Launch Safety; Take-off/Launch System Interfacing; Take-off/Launch Performance; Transition to Normal Flight; Control of Aircraft During Take-off/Launch

When applicable, this section provides information and details of relevant flight characteristics of the UAS airborne sub-systems under consideration, in respect of assisted take-offs or launches. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Take-off/Launch Safety[17] - During assisted take-off and launch, safety requirements apply to the safe operation of any associated equipment, the safe take-off/launch of the relevant aircraft, the safety of personnel and the safety of the public.	Describe all safety procedures, preparations, precautions and limitations that are associated with assisted take-offs and launches.
Take-off/Launch System Interfacing - The interfacing between the take-off/launch system and the aircraft must be demonstrated to be incapable of causing interference with the aircraft and its control during take-off/launch.	Identify and describe all interfaces between the take-off/launch system and the aircraft, as well as safety procedures, precautions, warnings and limitations applicable during take-off/launch.
Take-off/Launch Performance[17] - The take-off/launch system must be demonstrated to be capable of ensuring safe and controllable flight of the aircraft after each take-off/launch for each anticipated configuration of the aircraft. - The performance of the aircraft or its powerplant may not be adversely affected by the take-off/launch system during take-off/launch.	Describe the take-off/launch characteristics and performance of the aircraft during assisted take-off/launch. Describe all relevant procedures, precautions, warnings, limitations and aircraft preparations required prior to, and applicable during take-off/launch.
Transition to Normal Flight[17]	Describe aircraft flight handling procedures (automated and manual), precautions and limits required to ensure a safe and controlled transition from assisted take-off/launch to normal flight.
Control of Aircraft during Take-off/Launch[17]	Define control authorities (automated, semi-automated or manual) for assisted take-off/launch and prescribe the relevant and necessary procedures, precautions and limitations to ensure safe and controlled take-offs/launches.

C-5.3.11 Section: Assisted Landing/Recovery

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Handling	Assisted Landing/Recovery	Landing/Recovery Safety; Aircraft Performance before Landing/Recovery; Landing/Recovery System Interfacing; Control of Aircraft During Landing/Recovery

When applicable, this section provides information and details of relevant flight characteristics of the UAS airborne sub-systems under consideration, in respect of assisted landing or recovery from flight. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Landing/Recovery Safety[17] - During assisted landing and recovery, safety requirements apply to the safe operation of any associated equipment, the safe landing/recovery of the relevant aircraft, the safety of personnel and the safety of the public.	Describe all safety procedures, preparations, precautions and limitations that are associated with assisted landings and recoveries.
Aircraft Performance before Landing/Recovery	Describe the flight characteristics and performance of the aircraft during assisted landing/recovery. Describe all relevant procedures, precautions, warnings, limitations and aircraft preparations required prior to, and applicable during landing/recovery.
Landing/Recovery System Interfacing - The interfacing between the aircraft and the landing/recovery system must be demonstrated to ensure safe and controlled landings/recoveries without adverse or unplanned resulting damage to the aircraft or the system elements.	Identify and describe all interfaces between the aircraft and the landing/recovery system, as well as safety procedures, precautions, warnings and limitations applicable during landing/recovery.
Control of Aircraft during Landing/Recovery	Define control authorities (automated, semi-automated or manual) for assisted landings/recoveries and prescribe the relevant and necessary procedures, precautions and limitations to ensure safe and controlled landings/recoveries.

C-5.3.12 Section: Emergency Landing/Recovery

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Handling	Emergency Landing/Recovery	Emergency Landing/Recovery Safety; Emergency Landing/Recovery System Interfacing; Control of Aircraft during Emergency Landing/Recovery

When applicable, this section provides information and details of relevant procedures and requirements applicable to the UAS airborne sub-systems under consideration, in respect of emergency landing or recovery. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Emergency Landing/Recovery Safety - During emergency landing and recovery, the safety of personnel and of the public should be considered and reasonable steps should be taken to minimise the risk to personnel and the public.	Describe all safety procedures, preparations, and precautions that are associated with emergency landings and recoveries.
Emergency Landing/Recovery System Interfacing - The emergency landing/recovery system (including recovery parachutes) must, as far as is practicable and reasonable under the relevant emergency conditions, attempt to ensure a safe and controlled landing/recovery.	Identify and describe all interfaces between the aircraft and the emergency landing/recovery system, as well as safety procedures, precautions, warnings and limitations applicable during an emergency landing/recovery.
Control of Aircraft during Emergency Landing/Recovery	Define control authorities (automated, semi-automated or manual) for emergency landings/recoveries and prescribe the relevant and necessary procedures, precautions and limitations to ensure, as far as is practicable and reasonable, safe and controlled landings/recoveries.

C-5.4 Sub-Part: Flight and Surface Operation Load Considerations

This sub-part must contain descriptions of, and provisions for, the relevant flight loads and applicable surface operation loads for the UAS airborne sub-systems under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Operation Load Considerations	Flight Loads	General; Flight Loads and Flight Load Considerations
		Control System Loads	General; Primary Control System Loads; Secondary Control System Loads; Limit Control Forces and Torques; Surface Gust Conditions
		Pitch Control Device Loads	General; Pitch Control Device Loads; Balancing Loads; Unsymmetrical Loads; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Yaw Control Device Loads	General; Yaw Control Device Loads; Balancing Loads; Unsymmetrical Loads; Outboard Fins and Winglets; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Roll Control Device Loads	General; Roll Control Device Loads; Balancing Loads; Unsymmetrical Loads; Trim Device Loads; Trim Device Effects; Surface Gust Loads
		Surface Operation Loads	General; Surface Operation Loads and Surface Operation Load Considerations
		Emergency Conditions	General
		Catapult Assisted and Rocket Assisted Take-Off Loads	Launch Loads; Trolley or Shuttle Loads; Rocket Assisted Take-off Loads
		Parachute Recovery System Loads	Parachute Recovery Loads; Extracting Devices; Sacrificial Elements; Aircraft Dragging on the Surface

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-5.4.1 Section: Flight Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Operation Load Considerations	Flight Loads	General; Flight Loads and Flight Load Considerations

This section describes the flight loads applicable to the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17]	Applicable flight loads must be determined for all anticipated configurations[17] and operations of the UAS airborne sub-systems under consideration (aircraft and otherwise). In this sub-section, these configurations and operations must be described, as well as specific precautions and limitations applicable to the respective airborne sub-systems.
Flight Loads[17,53] and Flight Load Considerations	Define and describe all flight loads that act on the structure of the respective UAS airborne sub-system. Typically, the following should be considered, appropriately expanded and/or tailored for the airborne sub-system: - gyroscopic and aerodynamic loads[17]; - symmetrical flight conditions[17]; - unsymmetrical flight conditions[17]; - flight envelope[17]; - flight envelope protection[17]; - design airspeeds[17]; - limit manoeuvring load factors[17]; - gust loads[17]; - pitching conditions; - yawing conditions[17]; - rolling conditions[17]; - powerplant loads[17]; - pressurised compartment loads[17]; and - thermal loads[25].

C-5.4.2 Section: Control System Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Operation Load Considerations	Control System Loads	General; Primary Control System Loads; Secondary Control System Loads; Limit Control Forces and Torques; Surface Gust Conditions

This section describes the loads that act on the control systems of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General	Where applicable, flight loads and loads resulting from surface operations that may act on the primary and secondary control systems of the UAS airborne sub-systems under consideration (aircraft and otherwise), must be determined. In this sub-section, the relevant primary and secondary control systems, and their constituent elements, must be identified and described. Although the primary control system is traditionally considered to include the flight control system of an aircraft, other controls may also be identified as elements of the primary control system.
Primary Control System Loads[17]	Define and describe all flight loads and loads resulting from surface operations that act on the elements of the primary control system of the respective UAS airborne sub-system.
Secondary Control System Loads[17]	Define and describe all flight loads and loads resulting from surface operations that act on the elements of the secondary control system of the respective UAS airborne sub-system.
Limit Control Forces and Torques[17]	Define and describe the control actuating forces and torques that act on the elements of the primary and secondary control system of the respective UAS airborne sub-system, as sell as the limits of these forces and torques.
Surface Gust Conditions[17]	Define and describe all anticipated loads resulting from surface gust conditions that will act on the elements of the primary and secondary control system of the respective UAS airborne sub-system.

C-5.4.3 Section: Pitch Control Device Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Operation Load Considerations	Pitch Control Device Loads	General; Pitch Control Device Loads; Balancing Loads; Unsymmetrical Loads; Trim Device Loads; Trim Device Effects; Surface Gust Loads

This section describes the loads that act on the pitch control devices of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General	Where applicable, flight loads and loads resulting from surface operations that may act on the pitch control devices of the UAS airborne sub-systems under consideration (aircraft and otherwise), must be determined. In this sub-section, the relevant pitch control devices, and their constituent elements, must be identified and described. Although the pitch control system on a fixed wing aircraft is traditionally considered to include a horisontal stabiliser and elevator or a canard, other pitch control devices such as warping/morphing skin surfaces and thrusters must also be included in this section.
Pitch Control Device Loads[17]	Define and describe all flight loads and loads resulting from surface operations that act on the pitch control devices of the respective UAS airborne sub-system.
Balancing Loads[17]	When pitch control surface balancing is applied, define and describe the loads resulting from the balancing device for all anticipated flight conditions.
Unsymmetrical Loads[17]	Define and describe all unsymmetrical loads that may act on the pitch control devices of the respective UAS airborne sub-system, as sell as the allowable limits of such unsymmetrical loads.
Trim Device Loads[17]	When pitch trim devices are utilised, define and describe all flight loads and loads resulting from surface operations that act on the pitch trim devices of the respective UAS airborne sub-system.
Trim Device Effects[17]	Define and describe the loads resulting from the trim devices on the pitch control devices or structural elements to which the trim devices are attached.
Surface Gust Loads[17]	Define and describe all anticipated loads resulting from surface gust conditions that will act on the pitch control and pitch trim devices of the respective UAS airborne sub-system.

C-5.4.4 Section: Yaw Control Device Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Operation Load Considerations	Yaw Control Device Loads	General; Yaw Control Device Loads; Balancing Loads; Unsymmetrical Loads; Outboard Fins and Winglets; Trim Device Loads; Trim Device Effects; Surface Gust Loads

This section describes the loads that act on the yaw control devices of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General	Where applicable, flight loads and loads resulting from surface operations that may act on the yaw control devices of the UAS airborne sub-systems under consideration (aircraft and otherwise), must be determined. In this sub-section, the relevant yaw control devices, and their constituent elements, must be identified and described. Although the yaw control system is traditionally considered to consist of a fin and rudder or a tail rotor, other yaw control devices such as warping/morphing skin surfaces and thrusters must also be considered in this section.
Yaw Control Device Loads[17]	Define and describe all flight loads and loads resulting from surface operations that act on the yaw control devices of the respective UAS airborne sub-system.
Balancing Loads[17]	When yaw control surface balancing is applied, define and describe the loads resulting from the balancing device for all anticipated flight conditions.
Unsymmetrical Loads[17]	Define and describe all unsymmetrical loads that may act on the yaw control devices of the respective UAS airborne sub-system, as sell as the allowable limits of such unsymmetrical loads.
Outboard Fins and Winglets[17]	When outboard fins or winglets are utilised, define and describe all flight loads and loads resulting from surface operations that act on the outboard fins or winglets of the respective UAS airborne sub-system. In addition, all loads resulting from the outboard fins or winglets on the horisontal surfaces to which they are attached, must also be defined and described[17].
Trim Device Loads[17]	When yaw trim devices are utilised, define and describe all flight loads and loads resulting from surface operations that act on the yaw trim devices of the respective UAS airborne sub-system.
Trim Device Effects[17]	Define and describe the loads resulting from the trim devices on the yaw control devices or structural elements to which the trim devices are attached.
Surface Gust Loads[17]	Define and describe all anticipated loads resulting from surface gust conditions that will act on the yaw control and yaw trim devices of the respective UAS airborne sub-system.

C-5.4.5 Section: Roll Control Device Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Operation Load Considerations	Roll Control Device Loads	General; Roll Control Device Loads; Balancing Loads; Unsymmetrical Loads; Trim Device Loads; Trim Device Effects; Surface Gust Loads

This section describes the loads that act on the roll control devices of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General	Where applicable, flight loads and loads resulting from surface operations that may act on the roll control devices of the UAS airborne sub-systems under consideration (aircraft and otherwise), must be determined. In this sub-section, the relevant roll control devices, and their constituent elements, must be identified and described. Although the roll control system is traditionally considered to consist of ailerons on fixed wing aircraft, other roll control devices such as spoilers, warping/morphing skin surfaces and thrusters must also be considered in this section.
Roll Control Device Loads[17]	Define and describe all flight loads and loads resulting from surface operations that act on the roll control devices of the respective UAS airborne sub-system.
Balancing Loads[17]	When roll control surface balancing is applied, define and describe the loads resulting from the balancing device for all anticipated flight conditions.
Unsymmetrical Loads[17]	Define and describe all unsymmetrical loads that may act on the roll control devices of the respective UAS airborne sub-system, as sell as the allowable limits of such unsymmetrical loads.
Trim Device Loads[17]	When roll trim devices are utilised, define and describe all flight loads and loads resulting from surface operations that act on the roll trim devices of the respective UAS airborne sub-system.
Trim Device Effects[17]	Define and describe the loads resulting from the trim devices on the roll control devices or structural elements to which the trim devices are attached.
Surface Gust Loads[17]	Define and describe all anticipated loads resulting from surface gust conditions that will act on the roll control and roll trim devices of the respective UAS airborne sub-system.

C-5.4.6 Section: Loads on Special Devices

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Operation Load Considerations	Loads on Special Devices	General; Flight and Surface Operation Loads; Unsymmetrical Loads; Surface Gust Loads; Device-specific Loads

This section describes the loads that act on all special devices, such as flaps, leading slats, external cargo bays and external munitions pylons, amongst others, utilised on the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General	Where applicable, flight loads and loads resulting from surface operations that may act on special devices utilised on the UAS airborne sub-systems under consideration (aircraft and otherwise), must be determined. In this sub-section, the relevant special devices, and their constituent elements, must be identified and described.
Flight and Surface Operation Loads[17]	Define and describe all flight loads and loads resulting from surface operations that act on the special devices of the respective UAS airborne sub-system.
Unsymmetrical Loads[17]	Define and describe all unsymmetrical loads that may act on the special devices of the respective UAS airborne sub-system, as sell as the allowable limits of such unsymmetrical loads.
Surface Gust Loads[17]	Define and describe all anticipated loads resulting from surface gust conditions that will act on the special devices of the respective UAS airborne sub-system.
Device-specific Loads	Define and describe device-specific loads that may result from the special devices on the structural elements to which the devices are attached.

C-5.4.7 Section: Surface Operation Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Operation Load Considerations	Surface Operation Loads	General; Surface Operation Loads and Surface Operation Load Considerations

This section describes the surface operation loads applicable to the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17]	Applicable surface operation loads must be determined for all anticipated configurations[17] and operations of the UAS airborne sub-systems under consideration (aircraft and otherwise). In this sub-section, these configurations and operations must be described, as well as specific precautions and limitations applicable to the respective airborne sub-systems.
Surface Loads[17,53] and Surface Operation Load Considerations	Define and describe all loads that are expected to act on the structure of the UAS airborne sub-system as a result of manoeuvring and operations on the surfaces on and from which the aircraft or airborne sub-system is expected to operate. Note that the surfaces include not only ground surfaces (prepared or unprepared), but also other surfaces such as water, snow, ship decks and rooftops, amongst others. Typically, the following should be considered, appropriately expanded and/or tailored for the airborne sub-system: - manoeuvring loads; - normal landing loads[17]; - abnormal landing loads[17]; - sideloads and unsymmetrical loads[17]; - jacking loads[17]; - towing loads[17]; - mooring loads; - loads due to uneven landing sites; and - gust loads.

C-5.4.8 Section: Emergency Conditions

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Operation Load Considerations	Emergency Conditions	General

This section describes the required/desired effects of loads resulting from emergency conditions which the UAS airborne sub-systems under consideration may experience. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17]	Emergency conditions may develop during any phase of operation of the UAS airborne sub-systems under consideration (aircraft and otherwise). The loads on the structure of the airborne sub-system resulting from an emergency condition will range from insignificant to catastrophic. Except where an airborne sub-system is a manned chase aircraft, resulting damage to the airborne sub-system as a result of an emergency condition is allowable. However, harm to public and property should be avoided as far as is reasonably possible. This sub-section must therefore describe the necessary procedures to be followed during an emergency condition, to limit damage to the airborne sub-system, and to prevent harm to public and property, as far as is reasonably achievable.

C-5.4.9 Section: Catapult Assisted and Rocket Assisted Take-Off Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Operation Load Considerations	Catapult Assisted and Rocket Assisted Take-Off Loads	Launch Loads; Trolley or Shuttle Loads; Rocket Assisted Take-off Loads

When applicable, this section describes the loads that act on the UAS aircraft during catapult or rocket assisted take-offs. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS aircraft.

SUB-SECTION	OPERABILITY CRITERIA
Launch Loads[17]	All loads on the UAS aircraft structure resulting from a catapult or rocket assisted take-off must be defined and described. Procedures, precautions and limitations must be identified to ensure that the loads on the aircraft do not exceed the structural limitations of the aircraft, both during normal and aborted take-offs[17].
Trolley or Shuttle Loads[17]	When a trolley or shuttle is used to accelerate the UAS aircraft during take-off, all loads that are transferred to the aircraft structure from the trolley or shuttle must be defined and described. Procedures, precautions and limitations must be identified to ensure that the loads on the aircraft do not exceed the structural limitations of the aircraft, both during normal and aborted take-offs[17].
Rocket Assisted Loads[17]	For a rocket assisted take-off, all loads that are transferred to the UAS aircraft structure by the rocket motor/s must be defined and described. Procedures, precautions and limitations must be identified to ensure that the loads on the aircraft do not exceed the structural limitations of the aircraft, both during normal and aborted take-offs[17]. Additional procedures and precautions must be defined to ensure that partial or unsymmetrical firing of rocket motors will not result in damage to the aircraft.

C-5.4.10 Section: Parachute Recovery System Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Flight and Surface Operation Load Considerations	Parachute Recovery System Loads	Parachute Recovery Loads; Extracting Devices; Sacrificial Elements; Aircraft Dragging on the Surface

When a UAS aircraft is equipped with a parachute recovery system, this section describes the loads that act on the aircraft during deployment of the recovery parachute. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS aircraft.

SUB-SECTION	OPERABILITY CRITERIA
Parachute Recovery Loads[17]	All loads on the UAS aircraft structure resulting from a parachute recovery must be defined and described. Procedures, precautions and limitations must be identified to ensure that the loads on the aircraft do not exceed the structural limitations of the aircraft, both during normal and aborted parachute recoveries.
Extracting Devices[17]	All loads that are transferred to the aircraft structure from the parachute extracting device must be defined and described. Procedures, precautions and limitations must be identified to ensure that the loads on the aircraft do not exceed the structural limitations of the aircraft. Additional procedures and precautions must be defined to ensure that the extracting device will not cause damage to the aircraft during normal and aborted parachute extraction.
Sacrificial Elements[17]	Procedures and precautions must be defined to ensure that no sacrificial elements that form part of the parachute recovery system, will cause damage to the aircraft during normal or aborted parachute recovery.
Aircraft Dragging on the Surface[17]	Procedures and precautions must be defined to ensure that the recovery parachute does not drag the aircraft along the landing surface subsequent to landing[17].

C-5.5 Sub-Part: Design and Construction

This sub-part must contain descriptions of, and provisions for, the design and construction of the UAS airborne sub-systems under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Flutter; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors
		Flight Management System	Flight Management System; Flight Safety System; Flight Control System; Autonomy; Health Monitors and Data Recorders
		Structures	Primary Structural Elements; Other Structural Elements; Flight Controls; Onboard Launch System Elements; Onboard Recovery System Elements
		Rotors	General
		Flight Control Devices	General; Surface Gust Conditions
		Control Systems	General
		Landing Gear	General
		Payload and Equipment Accommodations - Internal and External	Internal Compartments; External Equipment Installations; External Payload Hardpoints
		Pressurisation and Environmental Control Systems	Pressurised Compartments; Environmental Control Systems
		Fire Protection	General; Fire Extinguishing Systems
		Miscellaneous	Levelling Means; Ballast Provisions
		Floats and Hulls	General
		Emergency Systems	Emergency Recovery Systems; Flight Termination Systems
		Electrical Systems	General
		Software	General; Software Maintenance
		Navigation and Communication Systems	General
		Mechanical Systems	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-5.5.1 Section: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Flutter; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors

This section provides general information regarding the design and construction of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Factors of Safety[17]	Define all design factors of safety that apply to the respective UAS airborne sub-systems and their components. Indicate compliance with relevant regulatory requirements for factors of safety.
Strength and Deformation[17,53]	Compile, identify and refer to substantiating engineering analyses and design reports proving that the respective UAS airborne sub-system structures will support the defined flight and surface loads with positive safety margins. The reports must also prove that no permanent deformation will occur under the defined load conditions and deformations will not interfere with the safe and effective operation of the airborne sub-system[17,53].
Materials[17]	Materials to be used in the construction of the UAS airborne sub-system structures must be shown to be appropriate for their intended purposes in terms of their material and strength properties. Procedures for the selection of appropriate materials, as well as for the manufacture of novel and new materials, must be documented and referred to in this section of the framework.
Fatigue Strength[17] and Evaluation[53] *<Continued Operability Entity>*	Each critical structural element that may be subject to fatigue loading must be identified, analysed and demonstrated to have adequate strength redundancy, and must be subjected to an appropriate fatigue inspection programme[53].
Flutter[17] *<Continued Operability Entity>*	Appropriate flutter analyses must be conducted for all UAS airborne sub-systems under consideration for which the effects of flutter would be catastrophic. The results of such analyses must be used to develop procedures, precautions and limitations to reduce or eliminate the potential of experiencing flutter. Compliance with regulatory requirements regarding flutter must also be demonstrated and reported.
Fabrication Methods and Workmanship[17]	Fabrication methods and workmanship should follow standard aeronautical or best industry practices as far as practicable. New fabrication methods and workmanship practices must be documented in detail to ensure consistency and repeatability in the application of such methods and practices.
Protection of Structure[17] *<Continued Operability Entity>*	Structures of UAS airborne sub-systems must be adequately protected[17] against deterioration and/or degradation caused by anticipated operational environmental hazards such as corrosion, abrasion, ageing and radiation.

Accessibility Provisions[17] *<Continued Operability Entity>*	Appropriate accessibility provisions must be made and described for each part of a UAS airborne sub-system that is subject to continued operability tasks such as inspections and maintenance[17].
Health Monitors and Data Recorders[25] *<Continued Operability Entity>*	When health monitors and/or data recorders are utilised for structural components and assemblies of the UAS airborne sub-systems, their functionality, interfaces, operation, and limitations must be described. It must also be shown that the data recorders, or any other method of recording data (eg live data link to an independent data recording facility), are secure and cannot be tampered with by crew or the public.
Icing, Lightning[9] and Other Environmental Protection[54] *<Continued Operability Entity>*	Define and describe all potential environmental risks and threats, such as chemical, biological, meteorological (such as icing and lightning), electrostatic, electromagnetic, thermal and solar radiation. Protective mechanisms and procedures must be designed, developed and described to prevent or limit adverse effects due to such environmental risks and threats to the UAS airborne sub-systems, and in particular to their structures.
Human Factors[25]	The design of a UAS airborne sub-system must provide adequately and appropriately for the continued involvement of humans in the operation and continued operability of the airborne sub-system throughout its serviceable life. This sub-section should define and describe anticipated roles and activities of humans in relation to the airborne sub-system under consideration.

C-5.5.2 Section: Flight Management System

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Flight Management System	Flight Management System; Flight Safety System; Flight Control System; Autonomy; Health Monitors and Data Recorders

This section provides information and details regarding flight management systems of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Flight Management System[55] <*Continued Operability Entity*>	The onboard flight management system is used to manage the flight of a UAS airborne sub-system from startup to shutdown. The system must be designed and constructed, or selected from existing systems, to be appropriate for the type of airborne sub-system under consideration and must be defined and described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the flight management system remains operable under all anticipated operating conditions, including during emergencies when appropriate levels of degraded functionality should be possible[55].
Flight Safety System[25] <*Continued Operability Entity*>	The flight safety system of a UAS airborne sub-system is used to monitor its flight status, and to ensure that public and property are not endangered in the event of a catastrophic failure. A flight termination system is typically included in the flight safety system[25]. The flight safety system must be designed and constructed, or selected from existing systems, to be appropriate for the type of airborne sub-system under consideration and must be defined and described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the flight safety system remains operable under all anticipated operating conditions, and particularly during emergencies.
Flight Control System[18, 25 ,55] <*Continued Operability Entity*>	The flight control system controls pitching, yawing and rolling[25] of a UAS airborne sub-system during flight and must be designed and constructed, or selected from existing systems, to be appropriate for the type of airborne sub-system under consideration and must be defined and described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the flight control system remains operable under all anticipated operating conditions, including during emergencies when appropriate levels of degraded functionality should be possible[55].
Autonomy[18] <*Continued Operability Entity*>	The level of autonomy and the automated functions of a UAS airborne sub-system must be designed to be appropriate for the type of airborne sub-system under consideration and must be defined and described. Procedures, precautions and limitations

	must be identified to ensure that the automated functions remain available under all anticipated operating conditions, including during emergencies.
Health Monitors and Data Recorders[25] <*Continued Operability Entity*>	Health monitors and/or data recorders utilised on the UAS airborne sub-systems under consideration must be designed and constructed, or selected from existing products, to be appropriate for the type of airborne sub-system under consideration and must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the health monitors and, in particular, the data recorders remain operable under all anticipated operating conditions, including during emergencies.

C-5.5.3 Section: Structures

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Structures	Primary Structural Elements; Other Structural Elements; Flight Controls; Onboard Launch System Elements; Onboard Recovery System Elements

This section provides information and details regarding the structures of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Primary Structural Elements[53] *<Continued Operability Entity>*	All primary structural elements of the UAS airborne sub-system under consideration must be identified and must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. Each primary structural element must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the primary structural elements remain operable under all anticipated operating conditions. Primary structural elements must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding primary structural elements must also be demonstrated and reported.
Other Structural Elements	Structural elements other than primary structural elements of the UAS airborne sub-system under consideration, such as landing gears and external store pylons, must be identified and must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. Such structural elements must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that these structural elements remain operable under all anticipated operating conditions. These structural elements must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding these structural elements must also be demonstrated and reported.
Flight Controls[25]	The flight controls of the UAS airborne sub-system under consideration must be identified and must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The flight controls must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the flight controls remain operable under all anticipated operating conditions,

	including emergency conditions. The flight controls must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure their continued operability. Compliance with relevant regulatory requirements regarding the design and construction of flight controls must also be demonstrated and reported.
Onboard Launch System Elements[18] <*Continued Operability Entity*>	Onboard launch system elements of the UAS airborne sub-system under consideration, other than standard landing gears, must be identified and must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. Such launch system elements must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the launch system elements remain operable. The launch system elements must be subjected to an appropriate engineering analysis, design and test process, from which an inspection, maintenance and rehabilitation programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding the launch system elements must also be demonstrated and reported.
Onboard Recovery System Elements[25] <*Continued Operability Entity*>	Onboard recovery system elements of the UAS airborne sub-system under consideration, other than standard landing gears, must be identified and must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. Such recovery system elements must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the recovery system elements remain operable. The recovery system elements must be subjected to an appropriate engineering analysis, design and test process, from which an inspection, maintenance and rehabilitation programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding the recovery system elements must also be demonstrated and reported.

C-5.5.4 Section: Rotors

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Rotors	General

When applicable, this section provides information and details regarding rotors of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[56] *<Continued Operability Entity>*	When rotors are utilised on the UAS airborne sub-system under consideration for lift generation or directional control, such rotors must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. Each rotor must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the rotor remains operable under all anticipated operating conditions. Each rotor must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard rotor design aspects, with emphasis on the following: - pressure venting and drainage of rotor blades; - mass balance; - rotor blade clearance; and - ground resonance prevention means[56]. Compliance with relevant regulatory requirements regarding rotors must also be demonstrated and reported.

C-5.5.5 Section: Flight Control Devices

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Flight Control Devices	General; Surface Gust Conditions

This section provides information and details regarding flight control devices of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[62] *<Continued Operability Entity>*	All flight control devices of the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. Each flight control device must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the flight control device remains operable under all anticipated operating conditions. Each flight control device must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding flight control devices must also be demonstrated and reported.
Surface Gust Conditions[62]	All anticipated loads resulting from surface gust conditions that act on the elements of the primary and secondary control system of the respective UAS airborne sub-system, must be defined and described, and must be considered in the design and development of the flight control devices.

C-5.5.6 Section: Control Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Control Systems	General

This section provides information and details regarding control systems of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[62] *<Continued Operability Entity>*	Each control system (flight control and otherwise) incorporated into the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. Each control system must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the control system remains operable under all anticipated operating conditions, including during emergencies. Each control system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding control systems must also be demonstrated and reported.

C-5.5.7 Section: Landing Gear

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Landing Gear	General

When applicable, this section provides information and details regarding the landing gear of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[62] *<Continued Operability Entity>*	The landing gears of the UAS airborne sub-systems under consideration, including skids, retractable landing gears and other unique designs, must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. Each landing gear must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the landing gear remains operable under all anticipated operating conditions. Each landing gear must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding landing gears must also be demonstrated and reported.

C-5.5.8 Section: Payload and Equipment Accommodations - Internal and External

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Payload and Equipment Accommodations - Internal and External	Internal Compartments; External Equipment Installations; External Payload Hardpoints

When applicable, this section provides information and details regarding the payload and equipment accommodations, external and internal, of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Internal Compartments[62] *<Continued Operability Entity>*	Internal payload and equipment compartments of the UAS airborne sub-systems under consideration must be designed and constructed to be appropriate for the airborne sub-system type under consideration. Each compartment must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements, particularly in respect of interfaces (mechanical, electrical, electronic, software or other) between the relevant payload or equipment and the compartment. Procedures, precautions and limitations must be identified to ensure that the compartment remains operable under all anticipated operating conditions, again in particular in respect of the interfaces. Each compartment must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following: - payload or equipment compartment doors and hatches; and - payload or equipment windows[62]. Compliance with relevant regulatory requirements regarding internal payload and equipment compartments must also be demonstrated and reported.
External Equipment Installations *<Continued Operability Entity>*	External equipment installations, such as stabilised cameras, winches and air-to-air re-fuelling points, which will be incorporated on the UAS airborne sub-systems under consideration, must be designed and constructed to be appropriate for the airborne sub-system type under consideration. Each installation must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements, particularly in respect of interfaces (mechanical, electrical, electronic, software or other) between the relevant equipment and the airborne sub-system (aircraft or otherwise). Procedures, precautions and limitations must be identified to ensure that the installation remains operable under all anticipated operating conditions, again in particular in respect of the interfaces. Each installation must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived

	to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following: - equipment/airborne sub-system interfaces; - equipment functioning; and - equipment access and serviceability. Compliance with relevant regulatory requirements regarding external equipment installations must also be demonstrated and reported.
External Payload Hardpoints <*Continued Operability Entity*>	External payload hardpoints for the UAS airborne sub-systems under consideration must be designed and constructed to be appropriate for the airborne sub-system type under consideration. Each hardpoint must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements, particularly in respect of interfaces (mechanical, electrical, electronic, software or other) between the relevant payload, the hardpoint and the airborne sub-system (aircraft or otherwise). Procedures, precautions and limitations must be identified to ensure that the hardpoint remains operable under all anticipated operating conditions, again in particular in respect of the interfaces. Each hardpoint must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following: - payload/hardpoint/airborne sub-system interfaces; - payload functioning (when applicable); and - hardpoint access and serviceability. Compliance with relevant regulatory requirements regarding internal payload and equipment compartments must also be demonstrated and reported.

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C-5.5.9 Section: Pressurisation and Environmental Control Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Pressurisation and Environmental Control Systems	Pressurised Compartments; Environmental Control Systems

When applicable, this section provides information and details regarding pressurisation and environmental systems of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Pressurised Compartments[62] *<Continued Operability Entity>*	Pressurised compartments and their associated pressurisation systems installed in the UAS airborne sub-systems under consideration, must be designed and constructed to be appropriate for the airborne sub-system type under consideration. Each compartment and system must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the compartment and system remain operable under all anticipated operating conditions. Each compartment and system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding pressurised compartments and their associated pressurisation systems must also be demonstrated and reported, particularly when humans and/or animals are to be transported in the pressurised compartment.
Environmental Control Systems[25] *<Continued Operability Entity>*	Environmental control systems installed on the UAS airborne sub-systems under consideration, must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. Each system must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements, particularly in respect of interfaces (mechanical, electrical, electronic, software or other) between the system and the airborne sub-system (aircraft or otherwise). Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions, again in particular in respect of the interfaces. Each system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding environmental control systems must also be demonstrated and reported, particularly when humans and/or animals are to be transported in the airborne sub-system.

C-5.5.10 Section: Fire Protection

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Fire Protection	General; Fire Extinguishing Systems

When applicable, this section provides information and details regarding fire protection and fire extinguishing systems in the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[62] *<Continued Operability Entity>*	Each system, component, compartment and tank of the UAS airborne sub-system under consideration that may lead to a catastrophic failure of the airborne sub-system if exposed to, or damaged by fire, must be protected from fire in a manner appropriate to the airborne sub-system type under consideration. The means of fire protection must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the means of fire protection remain operable under all anticipated operating conditions. The means of fire protection must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding fire protection must also be demonstrated and reported.
Fire Extinguishing Systems *<Continued Operability Entity>*	Each fire extinguishing system installed in the UAS airborne sub-system under consideration, must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. Each system must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements, particularly in respect of inspections, maintenance and testing. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions. Each system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding fire extinguishing systems must also be demonstrated and reported.

C-5.5.11 Section: Miscellaneous

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Miscellaneous	Levelling Means; Ballast Provisions

This section provides information and details regarding miscellaneous design and construction aspects of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Levelling Means[17,56] *<Continued Operability Entity>*	When construction, assembly and rigging requires the UAS airborne sub-system under consideration to be in a level position, means must be provided for placing the airborne sub-system in a level position. Appropriate means must also be provided to determine whether the airborne sub-system is level[17,56].
Ballast Provisions[56] *<Continued Operability Entity>*	When provision must be made for ballast in the UAS airborne sub-system under consideration, the ballast provision must be designed and constructed such as to ensure that the correct ballast type and mass is carried, movement of the ballast during operations cannot occur[56], and unauthorised tampering with the ballast is prevented. Procedures, precautions and limitations must be identified to ensure that no flight operations of the airborne sub-system can commence unless the correct ballast is installed.

C-5.5.12 Section: Floats and Hulls

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Floats and Hulls	General

When applicable, this section provides information and details regarding floats and hulls of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[56] *<Continued Operability Entity>*	When floats and/or hulls are to be incorporated on the UAS airborne sub-systems under consideration, the floats and hulls must be designed and constructed to be appropriate for the airborne sub-system type under consideration. Each float (main and auxiliary) must be described in terms of its components, characteristics, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the floats and hulls remain operable under all anticipated operating conditions. The floats and hulls must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following: - float buoyancy; - float design; - float strength; - hull buoyancy; - hull design; and - hull strength[56]. Compliance with relevant regulatory requirements regarding floats and hulls, including environmental concerns, must also be demonstrated and reported.

C-5.5.13 Section: Emergency Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE ELEMENTS OPERABILITY CRITERIA			
	Design and Construction	Emergency Systems	Emergency Recovery Systems; Flight Termination Systems

This section provides information and details regarding emergency systems of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Emergency Recovery Systems[4,55] <*Continued Operability Entity*>	Emergency recovery systems, including emergency recovery procedures for certain types of failures, for the UAS airborne sub-systems under consideration must be designed and constructed to be appropriate for the airborne sub-system type under consideration. Each recovery system must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the recovery system remains operable under all anticipated operating conditions, and in particular during emergencies. Each recovery system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Emergency recovery procedures must be demonstrated to be capable of preventing harm to public and property as far as is reasonably practicable. Compliance with relevant regulatory requirements regarding emergency recovery systems must also be demonstrated and reported.
Flight Termination Systems[55,57] <*Continued Operability Entity*>	The flight termination system, including its constituent components, that is to be used on the UAS airborne sub-systems under consideration must be designed and constructed, or selected from existing products, to be fail-safe[55] and to be appropriate for the airborne sub-system type under consideration. The system must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions, and in particular during emergencies. The system, and any emergency recovery procedures that may be included in the flight termination process, must be subjected to an appropriate engineering analysis, design and test process, from which an inspection, maintenance and test programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding flight termination systems must also be demonstrated and reported.

C-5.5.14 Section: Electrical Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Electrical Systems	General

This section provides information and details regarding electrical systems of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17,25,55] *<Continued Operability Entity>*	The electrical system of the UAS airborne sub-system under consideration must be designed and constructed to be appropriate for the airborne sub-system type under consideration. The electrical system must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions, and in particular during emergencies. The electrical system and its components must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[17,25]: - generation and distribution of electrical power; - provision of emergency power; - electrical wiring and wiring looms; - external power connections; - electrical bonding; - fire protection of the electrical system; and - protection of the electrical system against lightning and static electricity. Compliance with relevant regulatory requirements regarding electrical systems must also be demonstrated and reported.

C-5.5.15 Section: Software

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Software	General; Software Maintenance

This section provides information and details regarding software used on the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[25,55] *<Continued Operability Entity>*	Software used on the UAS airborne sub-system under consideration must be designed, or selected from existing software products, and demonstrated to be appropriate for the airborne sub-system type under consideration. All software must be verified and validated against an acceptable software design assurance standard such as RTCA DO-178 or equivalent[55]. Software used in simulations and models that may affect UAS safety must also be subjected to the software design assurance process[25]. All software must be subjected to an appropriate software engineering analysis, design and test process, from which an appropriate software maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding software must also be demonstrated and reported.
Software Maintenance *<Continued Operability Entity>*	The design and development of software used on the UAS airborne sub-system under consideration must be accomplished in a manner that allows easy and effective fault diagnosis and maintenance of the software, as well as software upgrades that may be required. The potential functional and safety effects of software obsolescence must also be addressed.

C-5.5.16 Section: Navigation and Communication Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Navigation and Communication Systems	General

This section provides information and details regarding navigation and communication systems of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[4,25,49,55] *<Continued Operability Entity>*	The navigation and communication systems of the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The navigation and communication systems must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the systems remain operable under all anticipated operating conditions, and in particular, where required, during emergencies. The navigation and communication systems must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[4,25,49]: - navigation systems; - flight instruments, displays and their interpretations; - communication systems; - communication links; and - frequency spectrum. Compliance with relevant regulatory requirements regarding navigation and communication systems must also be demonstrated and reported.

C-5.5.17 Section: Mechanical Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Mechanical Systems	General

This section provides information and details regarding mechanical systems of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[4,17] *<Continued Operability Entity>*	The mechanical systems of the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The mechanical systems must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the systems remain operable under all anticipated operating conditions, and in particular, where required, during emergencies. The mechanical systems must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[4,17]: - mechanical systems, including systems such as cable controls and mechanical launch elements; - hydraulic systems; - pneumatic systems; and - thermal protection, for operations in hostile and/or extreme environmental conditions. Compliance with relevant regulatory requirements regarding mechanical systems must also be demonstrated and reported.

C-5.6 Sub-Part: Powerplant and Powerplant Installation

This sub-part must contain descriptions of, and provisions for, the powerplant and powerplant installation of the UAS airborne sub-systems under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Powerplant and Powerplant Installation	General	Powerplant Type; Powerplant Installation; Rotor and Power Transmission Systems
		Powerplant Systems	General; Transmissions and Gearboxes
		Fuel Systems	General; In-flight Refuelling Systems
		Energy Storage Systems	General
		Powerplant Fire Protection	General
		Powerplant Controls and Accessories	Powerplant Controls; Powerplant Accessories

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-5.6.1 Section: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Powerplant and Powerplant Installation	General	Powerplant Type; Powerplant Installation; Rotor and Power Transmission Systems

When applicable, this section provides general information and details regarding the powerplant and powerplant installation of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	**OPERABILITY CRITERIA**
Powerplant Type[25] *<Continued Operability Entity>*	The powerplant of the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The powerplant must be described in terms of its components, characteristics, performance, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the powerplant remains operable under all anticipated operating conditions. Each new powerplant type must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard powerplant design aspects, with emphasis on the following[4,17,25]: - powerplant type, including engine, electrical motor, rocket motor and propeller selection, as applicable; - powerplant performance; - powerplant operating characteristics; - powerplant installation; - power transmission, including gearboxes and other means of power transmission; - negative acceleration; - powerplant thermal protection; and - noise and emissions. Compliance with relevant regulatory requirements regarding powerplants must also be demonstrated and reported.
Powerplant Installation *<Continued Operability Entity>*	The installation of the powerplant of the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The installation must be described in terms of its components, characteristics, and continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the installation remains operable under all anticipated operating conditions. Each new powerplant installation must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding powerplant installations must also be demonstrated and reported.

Rotor and Power Transmission Systems[53,56] <*Continued Operability Entity*>	When applicable, rotor and associated power transmission systems for the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The rotor and transmission system must be described in terms of its components, characteristics, performance, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions. Each rotor and transmission system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding rotor and associated power transmission systems must also be demonstrated and reported.

C-5.6.2 Section: Powerplant Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Powerplant and Powerplant Installation	Powerplant Systems	General; Transmissions and Gearboxes

When applicable, this section provides general information and details regarding powerplant systems of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17,25] *<Continued Operability Entity>*	Each system associated with the powerplant of the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The powerplant systems to be considered as applicable, include, but are not limited to: - mechanical systems; - hydraulic systems; - pneumatic systems; - electrical systems; - oil systems and oil tanks; - cooling and liquid cooling systems; - air induction systems; and - exhaust systems and exhaust heat exchangers. The relevant powerplant systems must be described in terms of their components, characteristics, performance, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that critical powerplant systems remain operable under all anticipated operating conditions. Each new powerplant system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding powerplant systems must also be demonstrated and reported.
Transmissions and Gearboxes[56] *<Continued Operability Entity>*	When applicable, transmissions and gearboxes associated with the powerplant of the UAS airborne sub-system under consideration, excluding rotor transmissions, must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The transmissions and gearboxes must be described in terms of their components, characteristics, performance, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the transmissions and gearboxes remain operable under all anticipated operating conditions. Each transmission and gearbox must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability.

	Compliance with relevant regulatory requirements regarding powerplant transmissions and gearboxes must also be demonstrated and reported.

C-5.6.3 Section: Fuel Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Powerplant and Powerplant Installation	Fuel Systems	General; In-flight Refuelling Systems

When applicable, this section provides general information and details regarding fuel systems of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[4,17,25] *<Continued Operability Entity>*	The fuel system and its components of the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The fuel system must be described in terms of its components, characteristics, performance, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the fuel system remains operable under all anticipated operating conditions. The fuel system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard fuel system design aspects, with emphasis on the following[4,17,25]: - fuel system design and installation; - fuel system lightning protection; - fuel flow, fuel lines and associated fuel flow hardware; - flow between interconnected tanks; - unusable fuel supply; - fuel system operation in hot and cold weather; - fuel tanks and fuel tank installation; and - pressure fuelling systems. Compliance with relevant regulatory requirements regarding fuel systems must also be demonstrated and reported.
In-flight Refuelling Systems *<Continued Operability Entity>*	When applicable, the in-flight refuelling system of the UAS airborne sub-system under consideration must be designed and constructed to be appropriate for the airborne sub-system type under consideration. The system must be described in terms of its components, characteristics, interfaces, performance, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions. The system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding in-flight refuelling must also be demonstrated and reported.

C-5.6.4 Section: Energy Storage Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Powerplant and Powerplant Installation	Energy Storage Systems	General

When applicable, this section provides general information and details regarding energy storage systems of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	**OPERABILITY CRITERIA**
General[17] *<Continued Operability Entity>*	Energy storage systems and their components, including fuel cells, of the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The system must be described in terms of its components, characteristics, performance, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions, including under emergency conditions. The system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard energy storage system design aspects, with emphasis on the following[17]: - storage battery design and installation; - fuel cell design and installation; - prevention of hazardous release of gases and liquids; - regulation of system temperature, power and voltage; - storage battery charging; and - storage battery or fuel cell failure sensing and warning devices. Compliance with relevant regulatory requirements regarding energy storage systems must also be demonstrated and reported.

C-5.6.5 Section: Powerplant Fire Protection

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE ELEMENTS OPERABILITY CRITERIA			
	Powerplant and Powerplant Installation	Powerplant Fire Protection	General

When applicable, this section provides general information and details regarding fire protection of the powerplant of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	The fire protection of the powerplant of the UAS airborne sub-system under consideration must be designed to be appropriate for the airborne sub-system type under consideration. The system must be described in terms of designated fire zones and the system's components, characteristics, performance, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions, including under emergency conditions. The system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard fire protection system design aspects, with emphasis on the following[17]: - firewalls; - firewall and other fire-resistant materials; - protection of cowlings, lines, fittings and components; - preventive and pre-cautionary measures, including fuel and hazardous fluid shut-off means, sealing of firewall openings, fire containment means; and - fire extinguishers. Compliance with relevant regulatory requirements regarding powerplant fire protection must also be demonstrated and reported.

C-5.6.6 Section: Powerplant Controls and Accessories

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Powerplant and Powerplant Installation	Powerplant Controls and Accessories	Powerplant Controls; Powerplant Accessories

When applicable, this section provides general information and details regarding powerplant controls and accessories of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Powerplant Controls[17] *<Continued Operability Entity>*	The powerplant controls of the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The controls must be described in terms of their components, characteristics, interfaces, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the controls remain operable under all anticipated operating conditions. The controls must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding powerplant controls must also be demonstrated and reported.
Powerplant Accessories[17] *<Continued Operability Entity>*	When applicable, the powerplant accessories of the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the powerplant and airborne sub-system types under consideration. The accessories must be described in terms of their components, characteristics, interfaces, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the accessories remain operable under all anticipated operating conditions. The controls must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding powerplant accessories must also be demonstrated and reported.

C-5.7 Sub-Part: Hazard and Collision Avoidance

This sub-part must contain descriptions of, and provisions for, hazard and collision avoidance systems for the UAS airborne sub-systems under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Hazard and Collision Avoidance	Hazard Avoidance Systems	General
		Collision Avoidance Systems	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-5.7.1 Section: Hazard Avoidance Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Hazard and Collision Avoidance	Hazard Avoidance Systems	General

When applicable, this section provides general information and details regarding hazard avoidance systems for the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[25] *<Continued Operability Entity>*	Hazard avoidance systems include procedures and devices that enable a UAS airborne sub-system to avoid hazards in flight as well as during surface operations. These hazards include, amongst others, obstacles on the ground, contaminated atmospheric conditions (such as volcanic ash), power lines, hazardous weather conditions, and other airspace users, unless the UAS mission is to engage such hazards. The hazard avoidance system of the UAS airborne sub-system under consideration must therefore be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The system must be described in terms of its components, characteristics, performance, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions. The system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding hazard avoidance systems must also be demonstrated and reported.

C-5.7.2 Section: Collision Avoidance Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Hazard and Collision Avoidance	Collision Avoidance Systems	General

This section provides information and details regarding collision avoidance systems for the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[4,25,49] <*Continued Operability Entity*>	Collision avoidance systems include procedures and devices that prevent UAS airborne sub-systems from causing harm to people and property due to collisions, both on the surface and in the air. Typical mechanical devices used for collision avoidance include, for example: - anti-collision lights; - navigation lights; - altitude alerting systems; - airborne collision avoidance systems (ACAS); - ground proximity warning systems (GPWS); and - terrain awareness and warning systems (TAWS)[4]. However, UAS collision avoidance systems must provide the UAS with equivalent or better collision avoidance capabilities than their manned counterparts[4]. The collision avoidance system for the UAS airborne sub-system under consideration must therefore be designed and constructed, or selected from existing products, to be appropriately capable for the type of airborne sub-system under consideration. The system must be described in terms of its components, characteristics, performance, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions. The system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding collision avoidance systems must also be demonstrated and reported.

C-5.8 Sub-Part: Avionics, Instruments and Equipment

This sub-part must contain descriptions of, and provisions for, avionics, instruments and equipment for the UAS airborne sub-systems under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Avionics, Instruments and Equipment	General	Software; Software Maintenance
		Communication and Navigation Equipment	Communication Equipment; Command and Control Data Link; Navigation Equipment
		Instruments and Sensors	General
		Automatic Take-off and Landing Systems	General; Manual and Automatic Abort Functions
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Safety Equipment and Emergency Capabilities	Safety Equipment; Emergency Capabilities
		Miscellaneous Equipment	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-5.8.1 Section: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Avionics, Instruments and Equipment	General	Software; Software Maintenance

This section provides information and details regarding software used in avionics, instruments and equipment on the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Software[25,55] <*Continued Operability Entity*>	Software included in existing avionics, instruments and equipment to be used for the UAS airborne sub-system under consideration, must be demonstrated to be appropriate for the airborne sub-system type under consideration. New software must be designed, developed, tested and demonstrated to be appropriate for the airborne sub-system type under consideration. All software must be verified and validated against an acceptable software design assurance standard such as RTCA DO-178 or equivalent[55]. Software used in simulations and models that may affect UAS safety must also be subjected to the software design assurance process[25]. All new software must be subjected to an appropriate software engineering analysis, design and test process, from which an appropriate software maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding software must also be demonstrated and reported.
Software Maintenance <*Continued Operability Entity*>	The design and development of new software for avionics, instruments and equipment to be used on the UAS airborne sub-system under consideration must be accomplished in a manner that allows easy and effective fault diagnosis and maintenance of the software, as well as software upgrades that may be required. The potential functional and safety effects of software obsolescence must also be addressed.

C-5.8.2 Section: Communication and Navigation Equipment

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Avionics, Instruments and Equipment	Communication and Navigation Equipment	Communication Equipment; Command and Control Data Link; Navigation Equipment

This section provides information and details regarding communication and navigation equipment of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Communication Equipment[4,17,25,49] *<Continued Operability Entity>*	The communication system and equipment used on the UAS airborne sub-system under consideration must be designed and developed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The system and equipment must be described in terms of their components, characteristics, performance, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system and equipment remain operable under all anticipated operating conditions. New equipment must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[17]: - communication system architecture; - system transparency to other airspace users; - electromagnetic interference protection; - electromagnetic compatibility; - communication system latency; and - frequency spectrum. In the case of an optionally piloted UAS, appropriate onboard communication equipment must be available for pilot use. Compliance with relevant regulatory requirements regarding communication equipment must also be demonstrated and reported.
Command and Control Data Link[4,17] *<Continued Operability Entity>*	The command and control data link for the UAS airborne sub-system under consideration must be appropriate for the airborne sub-system type under consideration, as well as for its level of autonomy. The data link and associated equipment must be described in terms of their components, characteristics, performance, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions, including under emergency conditions. New equipment must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[17]:

	- data link architecture and security; - electromagnetic interference and compatibility; - data link latency; - data link loss strategy; - data link antenna maskings; - data link change over procedures and parameters. Compliance with relevant regulatory requirements regarding command and control data links must also be demonstrated and reported.
Navigation Equipment[4,17,25] *<Continued Operability Entity>*	The navigation equipment used on the UAS airborne sub-system under consideration must be designed and developed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The equipment must be described in terms of their components, characteristics, performance, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions, including under emergency conditions. New equipment must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following: - navigation capabilities appropriate for the type of airborne sub-system, as well as for its level of autonomy; and - in the case of optionally piloted UAS, appropriate onboard navigation equipment for pilot use. Compliance with relevant regulatory requirements regarding navigation equipment must also be demonstrated and reported.

C-5.8.3 Section: Instruments and Sensors

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Avionics, Instruments and Equipment	Instruments and Sensors	General

This section provides information and details regarding instruments and sensors, excluding payload instruments and sensors, that are used for the operation of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	The instruments and sensors used for the operation of the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The instruments and sensors must be described in terms of their characteristics, performance, functions, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the instruments and sensors remain operable under all anticipated operating conditions, including under emergency conditions. New instruments and sensors must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[17]: - flight parameter sensors and instruments; - hazard and collision avoidance sensors; - navigational sensors and instruments; - flight control sensors; and - powerplant sensors and instruments. In the case of optionally piloted UAS, appropriate data display devices must be included with the sensors and instruments for pilot use. Compliance with relevant regulatory requirements regarding instruments and sensors must also be demonstrated and reported.

C-5.8.4 Section: Automatic Take-Off and Landing Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Avionics, Instruments and Equipment	Automatic Take-off and Landing Systems	General; Manual and Automatic Abort Functions

When applicable, this section provides information and details regarding automatic take-off and landing systems used on the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	When an automatic take-off and/or landing system is to be used on the UAS airborne sub-system under consideration, the system must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The system must be described in terms of its characteristics, performance, functions, interfaces, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions. In particular, an automatic landing system must also be shown to remain operable under emergency conditions when an automatic recovery landing/crash landing is required. New systems must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding automatic take-off and landing systems must also be demonstrated and reported.
Manual and Automatic Abort Functions[17] *<Continued Operability Entity>*	When an automatic take-off and/or landing system is to be used on the UAS airborne sub-system under consideration, the system must be provided with a manual abort function to allow the UAS crew to abort a take-off or landing manually from the remote control station[17]. An aborted landing will typically be followed by a go-around[17], or in the case of an unrecoverable emergency, a safe recovery, landing or crash landing at a different location. In addition to the manual abort function, the system must also include an automatic abort function to allow onboard, automatic take-off or landing abort in the event of an onboard failure that may prevent a safe take-off, flight or landing[17]. Procedures, precautions and limitations must be identified for the activation of the abort functions. Compliance with relevant regulatory requirements regarding automatic take-off and landing system abort functions must also be demonstrated and reported.

C-5.8.5 Section: Electrical Equipment

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Avionics, Instruments and Equipment	Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems

When applicable, this section provides information and details regarding electrical equipment used on the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	**OPERABILITY CRITERIA**
General[17] <*Continued Operability Entity*>	Electrical equipment used on the UAS airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the electrical system of the airborne sub-system type under consideration. The equipment must be described in terms of their characteristics, functions, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions, and in particular during emergencies. New equipment must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding electrical equipment must also be demonstrated and reported.
Batteries[17] <*Continued Operability Entity*>	Batteries used on the UAS airborne sub-system under consideration must be designed and developed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The batteries must be described in terms of their characteristics, performance, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the batteries remain operable under all anticipated operating conditions, including under emergency conditions. New battery designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding batteries must also be demonstrated and reported.
Circuit Protection Devices[17] <*Continued Operability Entity*>	Appropriate circuit protection devices, including fuses, circuit breakers and/or other acceptable devices, must be installed in at least all flight safety critical electrical circuits of the UAS airborne sub-system under consideration. The protection devices must be described in terms of their characteristics, performance, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the protection devices remain operable under all anticipated operating conditions, including under emergency conditions. New types of circuit protection devices must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance

	programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding circuit protection devices must also be demonstrated and reported.
Switches[17] *<Continued Operability Entity>*	Switches, including a master switch, must be installed to ensure the operability of the UAS airborne sub-system under consideration and must be designed and constructed, or selected from existing products, to be appropriate for the electrical system of the airborne sub-system type under consideration. The switches must be described in terms of their characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the switches remain operable under all anticipated operating conditions. New switch designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. In the case of optionally piloted UAS, appropriate switches must be installed for pilot use. Compliance with relevant regulatory requirements regarding electrical switches must also be demonstrated and reported.
Lights and Lighting Systems[17] *<Continued Operability Entity>*	When required, lights and lighting systems must be installed on the UAS airborne sub-system under consideration and must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The installation of the following lights must be considered, as appropriate and as required by relevant regulations: - taxi and landing lights[17,53]; - position lights[17,55]; - anti-collision lights[17,55]; - internal lighting for optionally piloted UAS; and - any other lights, such as searchlights that may be required for the anticipated operations of the UAS. The lights and lighting systems must be described in terms of their characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the lights and lighting systems remain operable under all anticipated operating conditions. New light and lighting system designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding lights and lighting systems must also be demonstrated and reported.

C-5.8.6 Section: Safety Equipment and Emergency Capabilities

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Avionics, Instruments and Equipment	Safety Equipment and Emergency Capabilities	Safety Equipment; Emergency Capabilities

This section provides information and details regarding safety equipment and associated emergency capabilities of the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Safety Equipment[4,17,25,49,55,57] *<Continued Operability Entity>*	When required, safety equipment must be installed on the UAS airborne sub-system under consideration and must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The safety equipment may include one or more of the following, as appropriate and as required by relevant regulations: - equipment associated with the flight safety system[25] - equipment associated with the hazard and collision avoidance systems[4,49]; - equipment associated with the flight termination system[55,57]; - fire extinguishing equipment; and - ice protection and de-icing equipment[17]. The safety equipment must be described in terms of their characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions, including under emergency conditions. New safety equipment designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding safety equipment must also be demonstrated and reported.
Emergency Capabilities[17] *<Continued Operability Entity>*	Utilising the relevant safety equipment, appropriate emergency capabilities must be developed for the UAS airborne sub-system under consideration. These capabilities include at least: - a procedure to shut down the engine/s and the capability to retain flight control of the airborne sub-system for as long as it can remain airborne[17]; and - an emergency recovery capability which includes a procedure to manoeuvre the airborne sub-system to a safe recovery, landing or crash landing location, and a flight termination system[17]. These capabilities, and their associated procedures and equipment, must be described in terms of their characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions, including under emergency conditions. New equipment designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be

	derived to ensure continued operability. Compliance with relevant regulatory requirements regarding emergency UAS capabilities must also be demonstrated and reported.

C-5.8.7 Section: Miscellaneous Equipment

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Avionics, Instruments and Equipment	Miscellaneous Equipment	General

This section provides information and details regarding miscellaneous equipment installed on the UAS airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17,25] *<Continued Operability Entity>*	When installed on the UAS airborne sub-system under consideration, the equipment listed below, and/or any other equipment not addressed elsewhere in this framework, must be designed and constructed, or selected from existing products, to be appropriate for the airborne sub-system type under consideration. The equipment may include one or more of the following, as appropriate: - health monitors and data recorders[25]; - electronic equipment not listed elsewhere in this framework[17]; - equipment containing high energy rotors[17]; - equipment associated with onboard environmental control systems[25]; - equipment associated with vacuum, pressurisation and pneumatic systems[17]; and/or - equipment associated with hydraulic systems[62]. The equipment must be described in terms of their characteristics, functions, performance, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions, including under emergency conditions. New equipment designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding the equipment must also be demonstrated and reported.

C-5.9 Sub-Part: Operating Limitations, Safety Information and System Manual

This sub-part must contain details of, and provisions for, operating limitations and safety information relevant to the UAS airborne sub-system under consideration. This sub-part must also describe and reference the system manual for the UAS airborne sub-system (aircraft or otherwise) under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manual	Operating Limitations	General
		Markings and Placards	General
		Aircraft/Airborne Sub-system Manual	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-5.9.1 Section: Operating Limitations

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manual	Operating Limitations	General

This section provides information and details of operating limitations relevant to the UAS aircraft/airborne sub-system under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS aircraft/airborne sub-system.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	The operating precautions and limitations identified under each relevant section and sub-section of this Part IIIB of the framework, and any other relevant operating limitations, must be consolidated and listed in an appropriate operating limitations reference document. This operating limitations reference document must be under configuration control. The operating precautions and limitations must also be included in the system manual for the UAS aircraft/airborne sub-system under consideration. Compliance with relevant regulatory requirements regarding the documentation of operating limitations must be demonstrated and reported.

C-5.9.2 Section: Markings and Placards

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manual	Markings and Placards	General

This section provides details regarding operating and safety markings and placards applicable to the UAS aircraft/airborne sub-system under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS aircraft/airborne sub-system.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	Appropriate operating and safety markings and placards to be installed in or on the UAS aircraft/airborne sub-system under consideration must be identified, designed and described in terms of their characteristics, contents, functions, installation details and their continued operability (maintenance) requirements. Compliance with relevant regulatory requirements regarding safety markings and placards must also be demonstrated and reported.

C-5.9.3 Section: Aircraft/Airborne Sub-System Manual

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manual	Aircraft/Airborne Sub-system Manual	General

This section describes and references the system manual for the UAS airborne sub-system (aircraft or otherwise) under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS aircraft/airborne sub-system.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	The relevant system, sub-system and component information identified under each applicable section and sub-section of this Part IIIB of the framework, must be consolidated and captured in an appropriate manner in the system manual for the UAS aircraft/airborne sub-system under consideration. The system manual, which may consist of one or more parts, must be under configuration control and emphasis should be placed on the following: - descriptions; - performance details; - operating precautions and limitations; - continued operability requirements; - data and information required by relevant regulations; and - any other data or information required to achieve and maintain operability of the UAS aircraft/airborne sub-system. Compliance with relevant regulatory requirements regarding the contents of the system manual must be demonstrated and reported.

C-5.10 Sub-Part: Continued Operability and Airworthiness

This sub-part must identify the continued operability and airworthiness requirements for the UAS airborne sub-system (aircraft or otherwise) under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Continued Operability and Airworthiness	Continued Operability and Airworthiness Requirements	General

The criteria relevant to this sub-part are presented in the following paragraph.

C-5.10.1 Section: Continued Operability and Airworthiness Requirements

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Continued Operability and Airworthiness	Continued Operability and Airworthiness Requirements	General

This section provides information and details regarding the continued operability and airworthiness requirements for the UAS aircraft/airborne sub-system under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS aircraft/airborne sub-system.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	The continued operability requirements identified under each relevant section and sub-section of this Part IIIB of the framework, and any other relevant continued operability and airworthiness requirements, must be consolidated and listed in an appropriate continued operability reference document. This continued operability reference document must be under configuration control. The continued operability requirements must also be included in the system manual for the UAS aircraft/airborne sub-system under consideration. Compliance with relevant regulatory requirements regarding instructions for continued airworthiness must be demonstrated and reported.

C-5.11 Sub-Part: Security

This sub-part must contain details of, and provisions for, appropriate security measures for the UAS airborne sub-system (aircraft or otherwise) under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Security	Aircraft/Airborne Sub-system Security	General

The criteria relevant to this sub-part are presented in the following paragraph.

C-5.11.1 Section: Aircraft/Airborne Sub-System Security

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIB - AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Security	Aircraft/Airborne Sub-system Security	General

This section provides information and details regarding appropriate security measures for the UAS aircraft/airborne sub-system under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS aircraft/airborne sub-system.

SUB-SECTION	OPERABILITY CRITERIA
General[4,49] *<Continued Operability Entity>*	Security risks associated with the UAS aircraft/airborne sub-system under consideration must be established and appropriate security measures must be developed, implemented and regularly updated to secure the aircraft/airborne sub-system against unlawful or malicious interference. Risks to be considered include at least the following: - vulnerability of communication and data links between the aircraft/airborne sub-system and other systems, including the remote control station[4]; - vulnerability of the crew of the UAS during operations[4]; - interception/hijacking of the aircraft/airborne sub-system for terrorist attacks[4]; - confidentiality of operations[49]; - security of interactive payloads[49]; and - security of military and commercial cargo. The risks and the security measures must be reviewed continuously in respect of new security risks and threats, in order to update the security measures on a regular basis. Compliance with relevant regulatory requirements regarding UAS security measures must be demonstrated and reported.

C-6. UAS OPERABILITY FRAMEWORK PART IIIC: NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA

This part provides general information and technical details of the UAS non-airborne sub-systems under consideration. The non-airborne sub-systems of the UAS usually include take-off/launch systems, landing/recovery systems, remote control stations, non-airborne communications relay devices, and any other non-airborne sub-systems that are considered to be sub-systems of the UAS. Non-airborne UAS sub-systems are typically considered to be man-carried, based on the ground or on water, on buildings, structures, vehicles, ships, submarines, or on any other non-airborne device. This part should therefore be used to address all such non-airborne sub-systems and should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

The table below gives a summary overview of the operability requirements and criteria included in the Framework for the purposes of this thesis.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Introduction		
	General	Applicability	
		Functions of Non-Airborne Sub-systems	
	Operating and Functional Characteristics	General	Verification and Validation
		Take-off/Launch System	General; Take-off/Launch System Safety
		Landing/Recovery System	General; Landing/Recovery System Safety; Emergency Landing/Recovery Safety
		Remote Control Station	General; Remote Control Station Safety
		Other Non-Airborne Support Systems	General; Support System Safety
	Load Considerations	Take-off/Launch System Loads	General
		Landing/Recovery System Loads	General
		Remote Control Station Loads	General
		Other Non-Airborne Support System Loads	General
		Emergency Conditions	General
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors; Transportability; Storage Provisions
		Structures	Primary Structural Elements; Other Structural Elements
		Controls and Equipment	General
		Internal Environment Control Systems	General
		Fire Protection	General; Fire Extinguishing Systems
		Environmental Hazards Protection	General
		Emergency Systems	General
		Electrical Systems	General
		Software	General; Software Maintenance
		Mechanical Systems	General
		Powerplants	General
	Instruments and Equipment	General	Software; Software Maintenance
		Communication Equipment	Communication Equipment; Command and Control Data Link
		Instruments and Sensors	General
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Safety Equipment and Emergency Capabilities	Safety Equipment
		Miscellaneous Equipment	General

	Operating Limitations, Safety Information and System Manuals	Operating Limitations	General
		Markings and Placards	General
		System Manuals	General
	Continued Operability	Continued Operability Requirements	General
	Security	Non-Airborne Sub-system Security	General

The criteria relevant to the sub-parts of this part are presented in the following paragraphs.

C-6.1 Sub-Part: Introduction

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Introduction		

This sub-part must introduce the part, describe its purpose and scope in respect of the UAS non-airborne sub-systems under consideration, and give a high-level overview of the non-airborne sub-systems of the respective UAS. The detail required in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-PART	OPERABILITY CRITERIA
Introduction	Introduce this part and describe its purpose and scope.

C-6.2 Sub-Part: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	General	Applicability	
		Functions of Non-Airborne Sub-systems	

This sub-part must define the non-airborne sub-systems applicable to the respective UAS under consideration, and must provide the scope of functions of the non-airborne sub-systems. The criteria listed in the table below should be tailored and expanded as appropriate.

SECTION	OPERABILITY CRITERIA
Applicability	Define and describe the respective UAS non-airborne sub-systems, including variants and derivatives, to which this section applies. The primary categories of non-airborne sub-systems include: - take-off/launch systems; - landing/recovery systems; - remote control stations; and - other non-airborne support systems.
Functions of the UAS Non-Airborne Sub-systems	Define and describe the scope of the functions that are contemplated for the respective UAS non-airborne sub-systems under consideration.

C-6.3 Sub-Part: Operating and Functional Characteristics

This sub-part must contain descriptions of the operating and functional characteristics of the UAS non-airborne sub-systems under consideration. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating and Functional Characteristics	General	Verification and Validation
		Take-off/Launch System	General; Take-off/Launch System Safety
		Landing/Recovery System	General; Landing/Recovery System Safety; Emergency Landing/Recovery Safety
		Remote Control Station	General; Remote Control Station Safety
		Other Non-Airborne Support Systems	General; Support System Safety

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-6.3.1 Section: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating and Functional Characteristics	General	Verification and Validation

This section provides general information related to the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Verification and Validation	Conformance to specifications must be verified - all non-airborne sub-systems. Compliance with requirements must be validated - all non-airborne sub-systems.

C-6.3.2 Section: Take-Off/Launch System

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating and Functional Characteristics	Take-off/Launch System	General; Take-off/Launch System Safety

When applicable, this section provides information and details of the operating and functional characteristics of the UAS take-off/launch system under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS take-off/launch system.

SUB-SECTION	OPERABILITY CRITERIA
General[4,17]	Provide a general overview of the operating and functional characteristics, including interfaces with other systems, of the take-off/launch system under consideration, particularly in the case of unique or novel designs.
Take-off/Launch System Safety[17] - During the operation and, where applicable, the transportation of the take-off/launch system, safety requirements apply to the safe operation of all associated equipment, the safe take-off/launch of the relevant aircraft, the safety of personnel, the safety of the public and the safety of property.	Describe all safety procedures, preparations, precautions and limitations that are associated with the operation and transportation of the take-off/launch system.

C-6.3.3 Section: Landing/Recovery System

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating and Functional Characteristics	Landing/Recovery System	General; Landing/Recovery System Safety; Emergency Landing/Recovery Safety

When applicable, this section provides information and details of the operating and functional characteristics of the UAS landing/recovery system under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS landing/recovery system.

SUB-SECTION	OPERABILITY CRITERIA
General[4,17]	Provide a general overview of the operating and functional characteristics, including interfaces with other systems, of the landing/recovery system under consideration, particularly in the case of unique or novel designs.
Landing/Recovery System Safety[17] - During the operation and, where applicable, the transportation of the landing/recovery system, safety requirements apply to the safe operation of all associated equipment, the safe landing/recovery of the relevant aircraft, the safety of personnel, the safety of the public and the safety of property.	Describe all safety procedures, preparations, precautions and limitations that are associated with the operation and transportation of the landing/recovery system.
Emergency Landing/Recovery Safety - During emergency landing and recovery, the safety of personnel and of the public should be considered and reasonable steps should be taken to minimise the risk to personnel and the public.	Describe all safety procedures, preparations, and precautions that are associated with emergency landings and recoveries.

C-6.3.4 Section: Remote Control Station

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating and Functional Characteristics	Remote Control Station	General; Remote Control Station Safety

This section provides information and details of the operating and functional characteristics of the UAS non-airborne remote control station under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS remote control station.

SUB-SECTION	OPERABILITY CRITERIA
General[17]	Provide a general overview of the operating and functional characteristics, including interfaces with other systems, of the non-airborne remote control station under consideration, particularly in the case of unique or novel designs. Remote control stations range from man-carried mobile control units to control station networks.
Remote Control Station Safety - During operation of the remote control station, and where applicable, during transportation of the remote control station, safety requirements apply to the safe operation of all associated equipment, the safety of personnel, safety of the public and safety of property.	Describe all safety procedures, preparations, precautions and limitations that are associated with the operation and transportation of the remote control station.

C-6.3.5 Section: Other Non-Airborne Support Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating and Functional Characteristics	Other Non-Airborne Support Systems	General; Support System Safety

This section provides information and details of the operating and functional characteristics of the UAS non-airborne support systems under consideration, other than take-off/launch systems, landing/recovery systems and remote control stations. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS support systems.

SUB-SECTION	OPERABILITY CRITERIA
General[4,17,25,57]	Provide a general overview of the operating and functional characteristics, including interfaces with other systems, of the non-airborne support systems under consideration. The support systems may include[25]: - tools; - ground support equipment, such as towing vehicles, refuelling equipment and auxiliary power supplies; - required infrastructure; - air conditioning systems; and - payload and cargo handling equipment.
Support System Safety - During the operation and, where applicable, the transportation of the support systems, safety requirements apply to the safe operation of all associated equipment, the safe handling of the relevant aircraft, the safety of personnel, the safety of the public and the safety of property.	Describe all safety procedures, preparations, precautions and limitations that are associated with the operation and transportation of the support systems.

C-6.4 Sub-Part: Load Considerations

This sub-part must contain descriptions of relevant loads, for engineering analysis and design purposes, on the UAS non-airborne sub-systems under consideration. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Load Considerations	Take-off/Launch System Loads	General
		Landing/Recovery System Loads	General
		Remote Control Station Loads	General
		Other Non-Airborne Support System Loads	General
		Emergency Conditions	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-6.4.1 Section: Take-Off/Launch System Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Load Considerations	Take-off/Launch System Loads	General

This section provides information and details of engineering analysis and design loads on the UAS take-off/launch system under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS take-off/launch system.

SUB-SECTION	OPERABILITY CRITERIA
General	Define and describe all engineering analysis and design loads that act on the respective take-off/launch system and its components. Typically, the following should be considered, appropriately expanded and/or tailored for the system: - structural loads due to handling, assembly and disassembly, as appropriate; - operating loads; - transportation loads; - jacking and anchoring loads; - loads resulting from meteorological effects; - powerplant loads; and - thermal loads (during rocket-assisted take-offs).

C-6.4.2 Section: Landing/Recovery System Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Load Considerations	Landing/Recovery System Loads	General

This section provides information and details of engineering analysis and design loads on the UAS landing/recovery system under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS landing/recovery system.

SUB-SECTION	OPERABILITY CRITERIA
General	Define and describe all engineering analysis and design loads that act on the respective landing/recovery system and its components. Typically, the following should be considered, appropriately expanded and/or tailored for the system: - structural loads due to handling, assembly and disassembly, as appropriate; - operating loads; - transportation loads; - jacking and anchoring loads; - loads resulting from meteorological effects; and - powerplant loads.

C-6.4.3 Section: Remote Control System Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Load Considerations	Remote Control Station Loads	General

This section provides information and details of engineering analysis and design loads on the UAS remote control station under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS remote control station.

SUB-SECTION	OPERABILITY CRITERIA
General	Define and describe all engineering analysis and design loads that act on the respective remote control station and its components. Typically, the following should be considered, appropriately expanded and/or tailored for the system: - structural loads due to handling; - operating loads; - transportation loads; - jacking and anchoring loads; - loads resulting from meteorological effects; and - powerplant loads.

C-6.4.4 Section: Other Support Systems Loads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Load Considerations	Other Support Systems Loads	General

This section provides information and details of engineering analysis and design loads on UAS non-airborne support systems under consideration, other than take-off/launch systems, landing/recovery systems and remote control stations. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS support systems.

SUB-SECTION	OPERABILITY CRITERIA
General	Define and describe all engineering analysis and design loads that act on the respective non-airborne support system and its components. Typically, the following should be considered, appropriately expanded and/or tailored for the system: - structural loads due to handling, assembly and disassembly, as appropriate; - operating loads; - transportation loads; - jacking and anchoring loads; - loads resulting from meteorological effects; - powerplant loads; and - thermal loads.

C-6.4.5 Section: Emergency Conditions

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Load Considerations	Emergency Conditions	General

This section describes the required/desired effects of loads resulting from emergency conditions which the UAS non-airborne sub-systems under consideration may experience. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17]	Emergency conditions may develop during any phase of operation of the UAS non-airborne sub-systems under consideration. The loads on the non-airborne sub-system resulting from an emergency condition will range from insignificant to catastrophic. Harm to personnel, public and property should be avoided as far as is reasonably possible. This sub-section must describe the necessary procedures to be followed during an emergency condition in order to limit damage to the non-airborne sub-system, and to prevent harm to personnel, public and property, as far as is reasonably achievable.

C-6.5 Sub-Part: Design and Construction

This sub-part must contain descriptions of, and provisions for, the design and construction of the UAS non-airborne sub-systems under consideration. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors; Transportability; Storage Provisions
		Structures	Primary Structural Elements; Other Structural Elements
		Controls and Equipment	General
		Internal Environment Control Systems	General
		Fire Protection	General; Fire Extinguishing Systems
		Environmental Hazards Protection	General
		Emergency Systems	General
		Electrical Systems	General
		Software	General; Software Maintenance
		Mechanical Systems	General
		Powerplants	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-6.5.1 Section: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors; Transportability; Storage Provisions

This section provides general information regarding the design and construction of the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Factors of Safety[17]	Define all design factors of safety that apply to the respective UAS non-airborne sub-systems and their components. Indicate compliance with relevant regulatory requirements for factors of safety.
Strength and Deformation[17,53]	Compile, identify and refer to substantiating engineering analyses and design reports proving that the respective UAS non-airborne sub-system structures and components will support the defined engineering analysis and design loads with positive safety margins. The reports must also prove that no permanent deformation will occur under the defined load conditions and deformations will not interfere with the safe and effective operation of the non-airborne sub-systems.
Materials[17]	Materials to be used in the construction of the UAS non-airborne sub-system structures must be shown to be appropriate for their intended purposes in terms of their material and strength properties. Procedures for the selection of appropriate materials, as well as for the manufacture of novel and new materials, must be documented and referred to in this section of the framework.
Fatigue Strength[17] and Evaluation[53] *<Continued Operability Entity>*	Each critical structural element that may be subject to fatigue loading must be identified, analysed and demonstrated to have adequate strength redundancy, and must be subjected to an appropriate fatigue inspection programme.
Fabrication Methods and Workmanship[17]	Fabrication methods and workmanship should follow best industry practices as far as practicable. New fabrication methods and workmanship practices must be documented in detail to ensure consistency and repeatability in the application of such methods and practices.
Protection of Structure[17] *<Continued Operability Entity>*	Structures of UAS non-airborne sub-systems must be adequately protected against deterioration and/or degradation caused by anticipated operational environmental hazards such as corrosion, abrasion, ageing, heat and radiation.
Accessibility Provisions[17] *<Continued Operability Entity>*	Appropriate accessibility provisions must be made and described for each part of a UAS non-airborne sub-system that is subject to continued operability tasks such as inspections and maintenance.
Health Monitors and Data Recorders[25] *<Continued Operability Entity>*	When health monitors and/or data recorders are utilised for UAS non-airborne sub-systems, their functionality, interfaces, operation, and limitations must be described. It must also be

	shown that the data recorders are secure and cannot be tampered with by crew or the public.
Icing, Lightning[9] and Other Environmental Protection[54] <*Continued Operability Entity*>	Define and describe all potential environmental risks and threats, such as dust, chemical, biological, meteorological (such as icing, rain and lightning), electrostatic, electromagnetic, thermal and solar radiation. Protective mechanisms and procedures must be designed, developed and described to prevent or limit adverse effects due to such environmental risks and threats to the UAS non-airborne sub-systems, and in particular to their structures.
Human Factors[25]	The design of a UAS non-airborne sub-system must provide adequately and appropriately for the continued involvement of humans in the operation and continued operability of the non-airborne sub-system throughout its serviceable life. This sub-section must define and describe anticipated roles and activities of humans in relation to the non-airborne sub-system under consideration.
Transportation	When applicable, the design of the UAS non-airborne sub-system must provide for the effective transportation of the sub-system by relevant and defined transportation means (human, road, sea, rail, air or otherwise). This section must define the details, provisions, procedures and limitations for transportation of the non-airborne sub-system under consideration.
Storage Provisions	When applicable, the design of the UAS non-airborne sub-system must provide for the effective short term and long term storage of the sub-system. This section must define the details, provisions, procedures and limitations for the storage of the non-airborne sub-system under consideration.

C-6.5.2 Section: Structures

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Structures	Primary Structural Elements; Other Structural Elements

This section provides information and details regarding the structures of the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Primary Structural Elements[53] *<Continued Operability Entity>*	All primary structural elements of the UAS non-airborne sub-system under consideration must be identified and must be designed and constructed, or selected from existing products, to be appropriate for the non-airborne sub-system type under consideration. Each primary structural element must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the primary structural elements remain operable under all anticipated operating conditions. Primary structural elements must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability.
Other Structural Elements	Structural elements other than primary structural elements of the UAS non-airborne sub-system under consideration must be identified and must be designed and constructed, or selected from existing products, to be appropriate for the non-airborne sub-system type under consideration. Such structural elements must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that these structural elements remain operable under all anticipated operating conditions. These structural elements must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability.

C-6.5.3 Section: Controls and Equipment

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Controls and Equipment	General

This section provides information and details regarding control systems and equipment of the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	Each control system and associated equipment incorporated into the UAS non-airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the non-airborne sub-system type under consideration. Each control system and associated equipment must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the control system and equipment remain operable under all anticipated operating conditions, including during emergencies. New control systems and new equipment must be subjected to appropriate engineering analysis, design and test processes, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding control systems and associated equipment must also be demonstrated and reported[17].

C-6.5.4 Section: Internal Environment Control Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Internal Environment Control Systems	General

When applicable, this section provides information and details regarding internal environment control systems of the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[25] *<Continued Operability Entity>*	Internal environment control systems installed in the UAS non-airborne sub-systems under consideration, such as air conditioning systems in manned remote control stations or equipment trailers, must be designed and constructed, or selected from existing products, to be appropriate for the non-airborne sub-system type under consideration. Each system must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements, particularly in respect of interfaces (mechanical, electrical, electronic, software or other) between the system and the non-airborne sub-system (remote control station or otherwise). Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions. Each system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding environmental control systems must also be demonstrated and reported, particularly when humans are to be accommodated in the non-airborne sub-system.

C-6.5.5 Section: Fire Protection

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Fire Protection	General; Fire Extinguishing Systems

When applicable, this section provides information and details regarding fire protection and fire extinguishing systems in the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	Each system, component, compartment and tank of the UAS non-airborne sub-system under consideration that may lead to a catastrophic failure of the non-airborne sub-system if exposed to, or damaged by fire, must be protected from fire in a manner appropriate to the non-airborne sub-system type under consideration. The means of fire protection must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the means of fire protection remain operable under all anticipated operating conditions. The means of fire protection must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding fire protection must also be demonstrated and reported.
Fire Extinguishing Systems *<Continued Operability Entity>*	Each fire extinguishing system installed in the UAS non-airborne sub-system under consideration, must be designed and constructed, or selected from existing products, to be appropriate for the non-airborne sub-system type under consideration. Each system must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements, particularly in respect of inspections, maintenance and testing. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions. Each system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding fire extinguishing systems must also be demonstrated and reported.

C-6.5.6 Section: Environmental Hazards Protection

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Environmental Hazards Protection	General

This section provides information and details regarding protection of the UAS non-airborne sub-systems under consideration against environmental hazards during operations, transportation and storage. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General *<Continued Operability Entity>*	Each UAS non-airborne sub-system under consideration that may experience a catastrophic failure if exposed to, or damaged by environmental hazards, must be protected from such hazards in a manner appropriate for the non-airborne sub-system type under consideration, and appropriate for the anticipated hazards. The means of protection must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the means of protection remain operable under all anticipated operating, transportation and storage conditions. The means of protection must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability.

C-6.5.7 Section: Emergency Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Emergency Systems	General

This section provides information and details regarding emergency systems of the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[4,55] *<Continued Operability Entity>*	Emergency systems, including emergency recovery procedures for certain types of failures, for the UAS non-airborne sub-systems under consideration must be designed and constructed to be appropriate for the non-airborne sub-system type under consideration. Each emergency system must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the emergency system remains operable under all anticipated operating conditions, and in particular during emergencies. Each emergency system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability.

C-6.5.8 Section: Electrical Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Electrical Systems	General

This section provides information and details regarding electrical systems of the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17,25,55] *<Continued Operability Entity>*	The electrical system of the UAS non-airborne sub-system under consideration must be designed and constructed to be appropriate for the non-airborne sub-system type under consideration. The electrical system must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions, and in particular during emergencies. The electrical system and its components must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[17,25]: - generation and distribution of electrical power; - provision of emergency power; - electrical wiring and wiring looms; - external power connections; - electrical bonding; - fire protection of the electrical system; and - protection of the electrical system against lightning and static electricity. Compliance with relevant regulatory requirements regarding electrical systems must also be demonstrated and reported.

C-6.5.9 Section: Software

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Software	General; Software Maintenance

This section provides information and details regarding software used on the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[25,55] *<Continued Operability Entity>*	Software used on the UAS non-airborne sub-system under consideration must be designed, or selected from existing software products, and demonstrated to be appropriate for the non-airborne sub-system type under consideration. All software must be verified and validated against an acceptable software design assurance standard such as RTCA DO-178 or equivalent[55]. Software used in simulations and models that may affect UAS safety must also be subjected to the software design assurance process[25]. All software must be subjected to an appropriate software engineering analysis, design and test process, from which an appropriate software maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding software must also be demonstrated and reported.
Software Maintenance *<Continued Operability Entity>*	The design and development of software used on the UAS non-airborne sub-system under consideration must be accomplished in a manner that allows easy and effective fault diagnosis and maintenance of the software, as well as software upgrades that may be required. The potential functional and safety effects of software obsolescence must also be addressed.

C-6.5.10 Section: Mechanical Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Mechanical Systems	General

This section provides information and details regarding mechanical systems of the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17,25] <*Continued Operability Entity*>	The mechanical systems of the UAS non-airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the non-airborne sub-system type under consideration. The mechanical systems must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the systems remain operable under all anticipated operating conditions, and in particular, where required, during emergencies. The mechanical systems must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[17,25]: - mechanical systems, including systems such as cable controls; - hydraulic systems; - pneumatic systems; and - thermal protection, for operations in hostile and/or extreme environmental conditions.

C-6.5.11 Section: Powerplants

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Design and Construction	Powerplants	General

When applicable, this section provides general information and details regarding the powerplant of the UAS non-airborne sub-system under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-system.

SUB-SECTION	OPERABILITY CRITERIA
General[25] *<Continued Operability Entity>*	The powerplant of the UAS non-airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the non-airborne sub-system type under consideration. The powerplant must be described in terms of its components, characteristics, performance, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the powerplant remains operable under all anticipated operating conditions. Each new powerplant type must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard powerplant design aspects, with emphasis on the following[4,17,25]: - powerplant type; - powerplant performance; - powerplant operating characteristics; - powerplant installation; - power transmission, including gearboxes and other means of power transmission; - powerplant thermal protection; and - noise and emissions. Compliance with relevant regulatory requirements regarding powerplants must also be demonstrated and reported.

C-6.6 Sub-Part: Instruments and Equipment

This sub-part must contain descriptions of, and provisions for, instruments and equipment for the UAS non-airborne sub-systems under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Instruments and Equipment	General	Software; Software Maintenance
		Communication Equipment	Communication Equipment; Command and Control Data Link
		Instruments and Sensors	General
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Safety Equipment and Emergency Capabilities	Safety Equipment
		Miscellaneous Equipment	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-6.6.1 Section: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Instruments and Equipment	General	Software; Software Maintenance

This section provides information and details regarding software used in instruments and equipment on the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Software[25,55] *<Continued Operability Entity>*	Software included in existing instruments and equipment to be used for the UAS non-airborne sub-system under consideration, must be demonstrated to be appropriate for the non-airborne sub-system type under consideration. New software must be designed, developed, tested and demonstrated to be appropriate for the non-airborne sub-system type under consideration. All software must be verified and validated against an acceptable software design assurance standard such as RTCA DO-178 or equivalent[55]. Software used in simulations and models that may affect UAS safety must also be subjected to the software design assurance process[25]. All new software must be subjected to an appropriate software engineering analysis, design and test process, from which an appropriate software maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding software must also be demonstrated and reported.
Software Maintenance *<Continued Operability Entity>*	The design and development of new software for instruments and equipment to be used on the UAS non-airborne sub-systems under consideration must be accomplished in a manner that allows easy and effective fault diagnosis and maintenance of the software, as well as software upgrades that may be required. The potential functional and safety effects of software obsolescence must also be addressed.

C-6.6.2 Section: Communication Equipment

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Instruments and Equipment	Communication Equipment	Communication Equipment; Command and Control Data Link

This section provides information and details regarding communication equipment used on the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Communication Equipment[4,17,25,49] <*Continued Operability Entity*>	The communication system and equipment used on the UAS non-airborne sub-system under consideration must be designed and developed, or selected from existing products, to be appropriate for the non-airborne sub-system type under consideration. The system and equipment must be described in terms of their components, characteristics, performance, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system and equipment remain operable under all anticipated operating conditions. New equipment must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[17]: - communication system architecture; - system transparency to other airspace users; - electromagnetic interference protection; - electromagnetic compatibility; - communication system latency; and - frequency spectrum. Compliance with relevant regulatory requirements regarding communication equipment must also be demonstrated and reported.
Command and Control Data Links[17,25] <*Continued Operability Entity*>	The command and control data links between the UAS non-airborne and airborne sub-systems under consideration must be appropriate for the sub-system types under consideration. The data link and associated equipment must be described in terms of their components, characteristics, performance, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions, including under emergency conditions. New equipment must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[17]:

	- data link architecture and security; - electromagnetic interference and compatibility; - data link latency; - data link loss strategy; - data link antenna maskings; - data link change over procedures and parameters. Compliance with relevant regulatory requirements regarding command and control data links must also be demonstrated and reported.

C-6.6.3 Section: Instruments and Sensors

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Instruments and Equipment	Instruments and Sensors	General

This section provides information and details regarding instruments and sensors, excluding payload instruments and sensors, that are used for the operation of the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	The instruments and sensors, including data display units of remote control stations[17], used for the operation of the UAS non-airborne sub-systems under consideration, must be designed and constructed, or selected from existing products, to be appropriate for the non-airborne sub-system types under consideration. The instruments and sensors must be described in terms of their characteristics, performance, functions, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the instruments and sensors remain operable under all anticipated operating conditions, including under emergency conditions. New instruments and sensors must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding instruments and sensors must also be demonstrated and reported[17].

C-6.6.4 Section: Electrical Equipment

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Instruments and Equipment	Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems

When applicable, this section provides information and details regarding electrical equipment used on the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	**OPERABILITY CRITERIA**
General[17] *<Continued Operability Entity>*	Electrical equipment used on the UAS non-airborne sub-system under consideration must be designed and constructed, or selected from existing products, to be appropriate for the electrical system of the non-airborne sub-system type under consideration. The equipment must be described in terms of their characteristics, functions, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions. New equipment must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding electrical equipment must also be demonstrated and reported.
Batteries[17] *<Continued Operability Entity>*	Batteries used on the UAS non-airborne sub-system under consideration must be designed and developed, or selected from existing products, to be appropriate for the non-airborne sub-system type under consideration. The batteries must be described in terms of their characteristics, performance, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the batteries remain operable under all anticipated operating conditions, including under emergency conditions. New battery designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding batteries must also be demonstrated and reported.
Circuit Protection Devices[17] *<Continued Operability Entity>*	Appropriate circuit protection devices, including fuses, circuit breakers and/or other acceptable devices, must be installed in at least all safety critical electrical circuits of the UAS non-airborne sub-system under consideration. The protection devices must be described in terms of their characteristics, performance, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the protection devices remain operable under all anticipated operating conditions, including under emergency conditions. New types of circuit protection devices

	must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding circuit protection devices must also be demonstrated and reported.
Switches[17] *<Continued Operability Entity>*	Switches, including a master switch, installed on the UAS non-airborne sub-systems under consideration must be designed and constructed, or selected from existing products, to be appropriate for the electrical systems of the non-airborne sub-system types under consideration. The switches must be described in terms of their characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the switches remain operable under all anticipated operating conditions. New switch designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding electrical switches must also be demonstrated and reported.
Lights and Lighting Systems[17] *<Continued Operability Entity>*	When required, lights and lighting systems must be installed on and in the UAS non-airborne sub-systems under consideration and must be designed and constructed, or selected from existing products, to be appropriate for the non-airborne sub-system types under consideration. The lights and lighting systems must be described in terms of their characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the lights and lighting systems remain operable under all anticipated operating conditions. New light and lighting system designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding lights and lighting systems must also be demonstrated and reported.

C-6.6.5 Section: Safety Equipment and Emergency Capabilities

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Instruments and Equipment	Safety Equipment and Emergency Capabilities	Safety Equipment

This section provides information and details regarding safety equipment and associated emergency capabilities of the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
Safety Equipment[4,17,25,49,55,57] *<Continued Operability Entity>*	When required, safety equipment must be installed on the UAS non-airborne sub-systems under consideration and must be designed and constructed, or selected from existing products, to be appropriate for the non-airborne sub-system types under consideration. The safety equipment must be described in terms of their characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions, including under emergency conditions. New safety equipment designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding safety equipment must also be demonstrated and reported.

C-6.6.6 Section: Miscellaneous Equipment

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Instruments and Equipment	Miscellaneous Equipment	General

This section provides information and details regarding miscellaneous equipment installed on the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17,25] *<Continued Operability Entity>*	When required for the UAS non-airborne sub-system under consideration, any functional or safety significant equipment not addressed elsewhere in this framework, must be designed and constructed, or selected from existing products, to be appropriate for the non-airborne sub-system type under consideration. The equipment must be described in terms of their characteristics, functions, performance, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions. New equipment designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Where applicable, compliance with relevant regulatory requirements regarding the equipment must also be demonstrated and reported.

C-6.7 Sub-Part: Operating Limitations, Safety Information and System Manuals

This sub-part must contain details of, and provisions for, operating limitations and safety information relevant to the UAS non-airborne sub-system under consideration. This sub-part must also describe and reference the system manual for the UAS non-airborne sub-system under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manuals	Operating Limitations	General
		Markings and Placards	General
		System Manuals	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-6.7.1 Section: Operating Limitations

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manuals	Operating Limitations	General

This section provides information and details of operating limitations relevant to the UAS non-airborne sub-system under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-system.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	The operating precautions and limitations identified under each relevant section and sub-section of this Part IIIC of the framework, and any other relevant operating limitations, must be consolidated and listed in an appropriate operating limitations reference document. In particular, operating procedures and limitations must be included for the following[17]: - aircraft hand over between remote control stations; - aircraft handover between crews; and - multiple aircraft control. The operating limitations reference document must be under configuration control. The operating precautions and limitations must also be included in the system manual for the UAS non-airborne sub-system under consideration. Compliance with relevant regulatory requirements regarding the documentation of operating limitations must be demonstrated and reported.

C-6.7.2 Section: Markings and Placards

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manuals	Markings and Placards	General

This section provides details regarding operating and safety markings and placards applicable to the UAS non-airborne sub-system under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-system.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	Appropriate operating and safety markings and placards to be installed in or on the UAS non-airborne sub-system under consideration must be identified, designed and described in terms of their characteristics, contents, functions, installation details and their continued operability (maintenance) requirements. Compliance with relevant regulatory requirements regarding safety markings and placards must also be demonstrated and reported.

C-6.7.3 Section: System Manuals

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manuals	System Manuals	General

This section describes and references the system manuals for the UAS non-airborne sub-systems under consideration, including the take-off/launch system manual, the landing/recovery system manual, the remote control station system manual and system manuals for any other non-airborne support system. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	The relevant system, sub-system and component information identified under each applicable section and sub-section of this Part IIIC of the framework, must be consolidated and captured in an appropriate manner in the system manual for each UAS non-airborne sub-system under consideration. The system manual, which may consist of one or more parts, must be under configuration control and emphasis should be placed on the following: - descriptions; - performance details; - operating precautions and limitations; - continued operability requirements; - data and information required by relevant regulations; and - any other data or information required to achieve and maintain operability of the UAS non-airborne sub-system. Compliance with relevant regulatory requirements regarding the contents of the system manual must be demonstrated and reported.

C-6.8 Sub-Part: Continued Operability

This sub-part must identify the continued operability requirements for the UAS non-airborne sub-systems under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Continued Operability	Continued Operability Requirements	General

The criteria relevant to this sub-part are presented in the following paragraph.

C-6.8.1 Section: Continued Operability Requirements

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Continued Operability	Continued Operability Requirements	General

This section provides information and details regarding the continued operability requirements for the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	The continued operability requirements identified under each relevant section and sub-section of this Part IIIC of the framework, and any other relevant continued operability requirements, must be consolidated and listed in an appropriate continued operability reference document. This continued operability reference document must be under configuration control. The continued operability requirements must also be included in the system manual for the UAS non-airborne sub-system under consideration. Compliance with relevant regulatory requirements regarding instructions for continued operability must be demonstrated and reported.

C-6.9 Sub-Part: Security

This sub-part must contain details of, and provisions for, appropriate security measures for the UAS non-airborne sub-systems under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Security	Non-Airborne Sub-system Security	General

The criteria relevant to this sub-part are presented in the following paragraph.

C-6.9.1 Section: Non-Airborne Sub-System Security

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIIC - NON-AIRBORNE SUB-SYSTEMS OPERABILITY CRITERIA			
	Security	Non-Airborne Sub-system Security	General

This section provides information and details regarding appropriate security measures for the UAS non-airborne sub-systems under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS non-airborne sub-systems.

SUB-SECTION	OPERABILITY CRITERIA
General[4,49] *<Continued Operability Entity>*	Security risks associated with the UAS non-airborne sub-systems under consideration must be established and appropriate security measures must be developed, implemented and regularly updated to secure the non-airborne sub-systems against unlawful or malicious interference. Risks to be considered include at least the following: - vulnerability of communication and data links between the aircraft/airborne sub-system and other systems, including the remote control station[4]; - vulnerability of the crew of the UAS during operations[4]; - interception/hijacking of the non-airborne sub-systems for terrorist attacks[4]; - confidentiality of operations[49]; - security of non-airborne sub-systems during operations, transportation and storage; and - security of equipment during operations. The risks and the security measures must be reviewed continuously in respect of new security risks and threats, in order to update the security measures on a regular basis. Compliance with relevant regulatory requirements regarding UAS security measures must be demonstrated and reported.

C-7. UAS OPERABILITY FRAMEWORK PART IIID: PAYLOAD OPERABILITY CRITERIA

This part provides general information and technical details of payloads for the UAS under consideration. UAS payloads will include cargo payloads and functional payloads. For the purposes of this study, the terms 'payload' and 'cargo' will not include human passengers or live animals. This part should be used to address all payloads and should be tailored and expanded as appropriate for the respective UAS under consideration. The table below gives a summary overview of the operability requirements and criteria included in the Framework for the purposes of this thesis.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Introduction		
	General	Applicability	
	General and Functional Characteristics	General	Verification and Validation
		Cargo Payloads	General; Payload Safety
		Functional Payloads	General; Payload Safety; Safety during UAS Emergency
	Load Considerations	Cargo Payloads	General
		Functional Payloads	General
		Emergency Conditions	General
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors; Transportability; Storage Provisions
		Structures	Primary Structural Elements; Other Structural Elements
		Controls and Equipment	General
		Fire Protection	General
		Environmental Hazards Protection	General
		Emergency Systems	General
		Electrical Systems	General
		Software	General; Software Maintenance
		Mechanical Systems	General
	Instruments and Equipment	General	Software; Software Maintenance
		Communication Equipment	Communication Equipment; Data Link
		Instruments and Sensors	General
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Miscellaneous Equipment	General
	Operating Limitations, Safety Information and System Manuals	Operating Limitations	General
		Markings and Placards	General
		System Manuals	General
	Continued Operability	Continued Operability Requirements	General
	Security	Payload Security	General

The criteria relevant to the sub-parts of this part are presented in the following paragraphs.

C-7.1 Sub-Part: Introduction

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Introduction		

This sub-part must introduce the part, describe its purpose and scope in respect of the UAS payloads under consideration, and give a high-level overview of the payloads of the respective UAS under consideration. The detail required in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-PART	OPERABILITY CRITERIA
Introduction	Introduce this part and describe its purpose and scope.

C-7.2 Sub-Part: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	General	Applicability	

This sub-part must define the payload types applicable to the respective UAS under consideration. The criteria listed in the table below should be tailored and expanded as appropriate.

SECTION	OPERABILITY CRITERIA
Applicability[17,25]	Define and describe the respective UAS payload types, including the scope of payloads in each type, to which this section applies. The primary categories of payloads include: - cargo payloads; - functional payloads; - internal payloads; and - external payloads. For the purposes of the current framework, 'cargo' and 'payload' will not include human passengers and live animals[25].

C-7.3 Sub-Part: General and Functional Characteristics

This sub-part must contain descriptions of the general and functional characteristics of the UAS payloads under consideration. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	General and Functional Characteristics	General	Verification and Validation
		Cargo Payloads	General; Payload Safety
		Functional Payloads	General; Payload Safety; Safety during UAS Emergency

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-7.3.1 Section: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	General and Functional Characteristics	General	Verification and Validation

This section provides general information related to the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
Verification and Validation	Conformance to specifications must be verified - all payloads. Compliance with requirements must be validated - all payloads.

C-7.3.2 Section: Cargo Payloads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	General and Functional Characteristics	Cargo Payloads	General; Payload Safety

When applicable, this section provides information and details of the required characteristics for cargo payloads for the UAS under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
General	Provide a general overview of the required characteristics, including dimensions, weights, types of cargo and cargo packaging/containers, of the cargo payloads for the UAS under consideration.
Payload Safety	Describe all safety procedures, preparations, precautions and limitations that are associated with the cargo payloads for the UAS under consideration.

C-7.3.3 Section: Functional Payloads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	General and Functional Characteristics	Functional Payloads	General; Payload Safety; Safety during UAS Emergency

When applicable, this section provides information and details of the operating and functional characteristics of functional payloads for the UAS under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
General	Provide a general overview of the operating and functional characteristics, including interfaces with other systems, of the functional payloads, internal and external, for the UAS under consideration, particularly in the case of unique or novel designs.
Payload Safety - During the operation of the functional payloads, safety requirements apply to the safe operation of all associated equipment, the safe operation of the relevant aircraft, the safety of personnel, the safety of the public and the safety of property.	Describe all safety procedures, preparations, precautions and limitations that are associated with the operation of the functional payloads for the UAS under consideration.
Safety during UAS Emergency - During a UAS emergency associated with the operation of a functional payload, the safety of personnel and of the public should be considered and reasonable steps should be taken to minimise the risk to personnel and the public.	Describe all safety procedures, preparations, and precautions that are associated with UAS emergencies associated with the operation of the functional payloads for the UAS under consideration.

C-7.4 Sub-Part: Load Considerations

This sub-part must contain descriptions of relevant loads, for engineering analysis and design purposes, on the UAS payloads under consideration. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Load Considerations	Cargo Payloads	General
		Functional Payloads	General
		Emergency Conditions	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-7.4.1 Section: Cargo Payloads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Load Considerations	Cargo Payloads	General

When applicable, this section provides information and details of engineering analysis and design loads on cargo payloads for the UAS under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
General	Define and describe all engineering analysis and design loads that may act on cargo payloads for the UAS under consideration. In particular, all operational loads on cargo payloads that are to be carried externally on the UAS aircraft must be defined and analysed. Typically, the following should be considered, appropriately expanded and/or tailored for the system: - structural loads due to handling and loading; - flight loads; - loads due to manoeuvring on the surface; - jacking and anchoring loads; and - loads resulting from meteorological effects.

C-7.4.2 Section: Functional Payloads

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Load Considerations	Functional Payloads	General

This section provides information and details of engineering analysis and design loads on functional payloads, internal and external, for the UAS under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS.

SUB-SECTION	OPERABILITY CRITERIA
General	Define and describe all engineering analysis and design loads that act on the respective functional payloads, internal and external, for the UAS under consideration. Typically, the following should be considered, appropriately expanded and/or tailored for the system: - structural loads due to handling, assembly, disassembly and loading, as appropriate; - operating loads; - flight loads; - loads due to manoeuvring on the surface; - jacking and anchoring loads; and - loads resulting from meteorological effects.

C-7.4.3 Section: Emergency Conditions

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Load Considerations	Emergency Conditions	General

This section describes the required/desired effects of loads resulting from emergency conditions which the UAS payloads under consideration may experience. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General	Emergency conditions may develop during any phase of operation of the UAS and aircraft under consideration. The loads on the payloads resulting from an emergency condition will range from insignificant to catastrophic. Harm to personnel, public and property should be avoided as far as is reasonably possible. This sub-section must describe the necessary procedures to be followed during an emergency condition in order to limit damage to the payloads, and to prevent harm to personnel, public and property, as far as is reasonably achievable.

C-7.5 Sub-Part: Design and Construction

This sub-part must contain descriptions of, and provisions for, the design and construction of the UAS payloads under consideration, and in particular of cargo containers and functional payloads. Note that this section does not cover the terminal functioning and effects of munitions carried onboard the UAS aircraft. The following table gives an overview of the scope of this sub-part:

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors; Transportability; Storage Provisions
		Structures	Primary Structural Elements; Other Structural Elements
		Controls and Equipment	General
		Fire Protection	General
		Environmental Hazards Protection	General
		Emergency Systems	General
		Electrical Systems	General
		Software	General; Software Maintenance
		Mechanical Systems	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-7.5.1 Section: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Design and Construction	General	Factors of Safety; Strength and Deformation; Materials; Fatigue Strength and Evaluation; Fabrication Methods and Workmanship; Protection of Structure; Accessibility Provisions; Health Monitors and Data Recorders; Icing, Lightning and Other Environmental Protection; Human Factors; Transportability; Storage Provisions

This section provides general information regarding the design and construction of the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
Factors of Safety[17]	Define all design factors of safety that apply to the respective UAS payloads and their components. Indicate compliance with relevant regulatory requirements for factors of safety.
Strength and Deformation[17,53]	Compile, identify and refer to substantiating engineering analyses and design reports proving that the respective UAS payload structures and components will support the defined engineering analysis and design loads with positive safety margins. The reports must also prove that no permanent deformation will occur under the defined load conditions and deformations will not interfere with the safe and effective operation of functional payloads.
Materials[17]	Materials to be used in the construction of the UAS payloads must be shown to be appropriate for their intended purposes in terms of their material and strength properties. Procedures for the selection of appropriate materials, as well as for the manufacture of novel and new materials, must be documented and referred to in this section of the framework.
Fatigue Strength[17] and Evaluation[53] *<Continued Operability Entity>*	Each critical structural element that may be subject to fatigue loading must be identified, analysed and demonstrated to have adequate strength redundancy, and must be subjected to an appropriate fatigue inspection programme.
Fabrication Methods and Workmanship[17]	Fabrication methods and workmanship should follow best industry practices as far as practicable. New fabrication methods and workmanship practices must be documented in detail to ensure consistency and repeatability in the application of such methods and practices.
Protection of Structures[17] *<Continued Operability Entity>*	Structures of UAS payloads must be adequately protected against deterioration and/or degradation caused by anticipated operational environmental hazards such as corrosion, abrasion, ageing, heat and radiation.
Accessibility Provisions[17] *<Continued Operability Entity>*	Appropriate accessibility provisions must be made and described for each part of a UAS payload that is subject to continued operability tasks such as inspections and maintenance.
Health Monitors and Data Recorders[25] *<Continued Operability Entity>*	When health monitors and/or data recorders are utilised for UAS payloads, their functionality, interfaces, operation, and limitations must be described. It must also be shown that the data recorders are secure and cannot be tampered with by crew or the public.
Icing, Lightning[9] and Other Environmental Protection[54] *<Continued Operability Entity>*	Define and describe all potential environmental risks and threats, such as dust, chemical, biological, meteorological (such as icing, rain and lightning), electrostatic, electromagnetic, thermal and solar radiation. Protective mechanisms and procedures must be

	designed, developed and described to prevent or limit adverse effects due to such environmental risks and threats to the UAS payloads, and in particular to their structures.
Human Factors[25]	The design of a UAS payload must provide adequately and appropriately for the continued involvement of humans in the operation and continued operability of the payload throughout its serviceable life. This sub-section must define and describe anticipated roles and activities of humans in relation to the payload under consideration.
Transportation	When applicable, the design of the UAS payload must provide for its effective transportation by the relevant and defined transportation means (human, road, sea, rail, air or otherwise). This section must define the details, provisions, procedures and limitations for transportation of the payload under consideration.
Storage Provisions	When applicable, the design of the UAS payload must provide for the effective short term and long term storage of the payload. This section must define the details, provisions, procedures and limitations for the storage of the payload under consideration.

C-7.5.2 Section: Structures

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Design and Construction	Structures	Primary Structural Elements; Other Structural Elements

This section provides information and details regarding the structures of the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
Primary Structural Elements[53] <*Continued Operability Entity*>	All primary structural elements of the UAS payloads under consideration must be identified and must be designed and constructed, or selected from existing products, to be appropriate for the payload type under consideration. Each primary structural element must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the primary structural elements remain operable under all anticipated operating conditions. Primary structural elements must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability.
Other Structural Elements	Structural elements other than primary structural elements of the UAS payload under consideration must be identified and must be designed and constructed, or selected from existing products, to be appropriate for the payload type under consideration. Such structural elements must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that these structural elements remain operable under all anticipated operating conditions. These structural elements must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability.

C-7.5.3 Section: Controls and Equipment

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Design and Construction	Controls and Equipment	General

When applicable, this section provides information and details regarding control systems and equipment of the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	Each control system and associated equipment incorporated into the UAS payload under consideration must be designed and constructed, or selected from existing products, to be appropriate for the payload type under consideration. Each control system and associated equipment must be described in terms of their components, characteristics, functions, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the control system and equipment remain operable under all anticipated operating conditions. New control systems and new equipment must be subjected to appropriate engineering analysis, design and test processes, from which inspection and maintenance programmes must be derived to ensure continued operability.

C-7.5.4 Section: Fire Protection

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Design and Construction	Fire Protection	General

When applicable, this section provides information and details regarding fire protection of the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	When catastrophic failure of the UAS payload and its carrying aircraft can result if the payload is exposed to, or is damaged by fire, the payload must be protected from fire in a manner appropriate to the payload and its carrying aircraft type. The means of fire protection must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the means of fire protection remain operable under all anticipated operating conditions. The means of fire protection must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding fire protection must also be demonstrated and reported.

C-7.5.5 Section: Environmental Hazards Protection

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Design and Construction	Environmental Hazards Protection	General

This section provides information and details regarding protection of the UAS payloads under consideration against environmental hazards during operations, transportation and storage. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General *<Continued Operability Entity>*	Each UAS payload under consideration that may experience a catastrophic failure if exposed to, or damaged by environmental hazards, must be protected from such hazards in a manner appropriate for the payload type under consideration, and appropriate for the anticipated hazards. The means of protection must be described in terms of their components, characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the means of protection remain operable under all anticipated operating, transportation and storage conditions. The means of protection must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability.

C-7.5.6 Section: Emergency Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Design and Construction	Emergency Systems	General

When applicable, this section provides information and details regarding emergency systems of the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[4,55] *<Continued Operability Entity>*	Emergency systems, including emergency recovery procedures for certain types of failures, for the UAS payloads under consideration must be designed and constructed to be appropriate for the payload type under consideration. Each emergency system must be described in terms of its components, characteristics, functions, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the emergency system remains operable under all anticipated operating conditions, and in particular during emergencies. Each emergency system must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability.

C-7.5.7 Section: Electrical Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Design and Construction	Electrical Systems	General

When applicable, this section provides information and details regarding electrical systems of the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[17,25,55] *<Continued Operability Entity>*	The electrical system of the UAS payload under consideration must be designed and constructed to be appropriate for the payload type under consideration, as well as to be compatible with the electrical system of the intended UAS carrying aircraft. The electrical system must be described in terms of its components, characteristics, functions, interfaces, power requirements, minimum operability capabilities and its continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system remains operable under all anticipated operating conditions. The electrical system and its components must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[17,25]: - generation and distribution of electrical power; - provision of emergency power, if required; - electrical wiring and wiring looms; - external power connections; - electrical bonding; - fire protection of the electrical system; and - protection of the electrical system against lightning and static electricity. Compliance with relevant regulatory requirements regarding electrical systems must also be demonstrated and reported.

C-7.5.8 Section: Software

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Design and Construction	Software	General; Software Maintenance

When applicable, this section provides information and details regarding software used on the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[25,55] *<Continued Operability Entity>*	Software used on the UAS payload under consideration must be designed, or selected from existing software products, and demonstrated to be appropriate for the payload type under consideration. When the payload is required to interface with the UAS aircraft system software and the aircraft functionality and safety is at risk, the payload software must be verified and validated against an acceptable software design assurance standard such as RTCA DO-178 or equivalent[55]. Software used in simulations and models that may affect UAS safety must also be subjected to the software design assurance process[25]. All payload software should be subjected to an appropriate software engineering analysis, design and test process, from which an appropriate software maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding software must also be demonstrated and reported.
Software Maintenance *<Continued Operability Entity>*	The design and development of software used on the UAS payload under consideration must be accomplished in a manner that allows easy and effective fault diagnosis and maintenance of the software, as well as software upgrades that may be required. The potential functional and safety effects of software obsolescence must also be addressed.

C-7.5.9 Section: Mechanical Systems

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Design and Construction	Mechanical Systems	General

This section provides information and details regarding mechanical systems and interfaces of the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[4,17] *<Continued Operability Entity>*	The mechanical systems and interfaces of the UAS payload under consideration must be designed and constructed, or selected from existing products, to be appropriate for the payload type and UAS aircraft type under consideration. The mechanical systems and interfaces of the payload may not cause any additional functional or safety risks to the UAS aircraft. The mechanical systems and interfaces must be described in terms of their components, characteristics, functions, interface specifications, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the systems remain operable under all anticipated operating conditions. The mechanical systems must be subjected to an appropriate engineering analysis, design and test process, from which an inspection and maintenance programme must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[4,17]: - mechanical systems, including systems such as cable controls; - hydraulic systems; - pneumatic systems; and - thermal protection, for operations in hostile and/or extreme environmental conditions.

C-7.6 Sub-Part: Instruments and Equipment

This sub-part must contain descriptions of, and provisions for, instruments and equipment for the UAS payloads under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Instruments and Equipment	General	Software; Software Maintenance
		Communication Equipment	Communication Equipment; Data Link
		Instruments and Sensors	General
		Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems
		Miscellaneous Equipment	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-7.6.1 Section: General

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Instruments and Equipment	General	Software; Software Maintenance

This section provides information and details regarding software used in instruments and equipment on the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
Software[25,55] *<Continued Operability Entity>*	Software included in existing instruments and equipment used in the UAS payload under consideration must be designed, or selected from existing software products, and demonstrated to be appropriate for the payload type under consideration. When the payload is required to interface with the UAS aircraft system software and the aircraft functionality and safety is at risk, the payload software must be verified and validated against an acceptable software design assurance standard such as RTCA DO-178 or equivalent[55]. Software used in simulations and models that may affect UAS safety must also be subjected to the software design assurance process[25]. All payload software should be subjected to an appropriate software engineering analysis, design and test process, from which an appropriate software maintenance programme must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding software must also be demonstrated and reported.
Software Maintenance *<Continued Operability Entity>*	The design and development of new software for instruments and equipment to be used in the UAS payload under consideration must be accomplished in a manner that allows easy and effective fault diagnosis and maintenance of the software, as well as software upgrades that may be required. The potential functional and safety effects of software obsolescence must also be addressed.

C-7.6.2 Section: Communication Equipment

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Instruments and Equipment	Communication Equipment	Communication Equipment; Data Link

When applicable, this section provides information and details regarding communication equipment used in the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
Communication Equipment[4,17,25,49] *<Continued Operability Entity>*	When applicable, the communication system and equipment used in the UAS payload under consideration must be designed and developed, or selected from existing products, to be appropriate for the payload type under consideration. The system and equipment must be described in terms of their components, characteristics, performance, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the system and equipment remain operable under all anticipated operating conditions. New equipment designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[17]: - communication system architecture; - system transparency to other airspace users; - electromagnetic interference protection; - electromagnetic compatibility; - communication system latency; and - frequency spectrum. Compliance with relevant regulatory requirements regarding communication equipment must also be demonstrated and reported.
Data Links[4,17] *<Continued Operability Entity>*	When applicable, data links between the UAS payload and other sub-systems of the UAS under consideration, must be appropriate for the payload and sub-system types under consideration. The data link and associated equipment must be described in terms of their components, characteristics, performance, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions, including under emergency conditions. New equipment designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. The engineering analysis and design process must include standard design aspects, with emphasis on the following[17]: - data link architecture and security; - electromagnetic interference and compatibility;

	- data link latency; - data link loss strategy; - data link antenna maskings; and - data link change-over procedures and parameters. Compliance with relevant regulatory requirements regarding data links must also be demonstrated and reported.

C-7.6.3 Section: Instruments and Sensors

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Instruments and Equipment	Instruments and Sensors	General

When applicable, this section provides information and details regarding instruments and sensors that are used in the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[17] <*Continued Operability Entity*>	When applicable, instruments and sensors used in the UAS payloads under consideration must be designed and constructed, or selected from existing products, to be appropriate for the payload types under consideration. The instruments and sensors must be described in terms of their characteristics, performance, functions, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the instruments and sensors remain operable under all anticipated operating conditions. New instrument and sensor designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability.

C-7.6.4 Section: Electrical Equipment

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Instruments and Equipment	Electrical Equipment	General; Batteries; Circuit Protection Devices; Switches; Lights and Lighting Systems

When applicable, this section provides information and details regarding electrical equipment used in the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	Electrical equipment used in UAS payloads under consideration must be designed and constructed, or selected from existing products, to be appropriate for the electrical system of the payload type under consideration. The equipment must be described in terms of their characteristics, functions, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions. New equipment designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding electrical equipment must also be demonstrated and reported.
Batteries[17] *<Continued Operability Entity>*	Batteries used in UAS payloads under consideration must be designed and developed, or selected from existing products, to be appropriate for the payload type under consideration. The batteries must be described in terms of their characteristics, performance, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the batteries remain operable under all anticipated operating conditions. New battery designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding batteries must also be demonstrated and reported.
Circuit Protection Devices[17] *<Continued Operability Entity>*	Appropriate circuit protection devices, including fuses, circuit breakers and/or other acceptable devices, must be installed in at least all safety critical electrical circuits of the UAS payload under consideration. The protection devices must be described in terms of their characteristics, performance, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the protection devices remain operable under all anticipated operating conditions, including under emergency conditions. New types of circuit protection devices must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with

	relevant regulatory requirements regarding circuit protection devices must also be demonstrated and reported.
Switches[17] <*Continued Operability Entity*>	Switches, including a master switch, installed on the UAS payloads under consideration must be designed and constructed, or selected from existing products, to be appropriate for the electrical systems of the payload types under consideration. The switches must be described in terms of their characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the switches remain operable under all anticipated operating conditions. New switch designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding electrical switches must also be demonstrated and reported.
Lights and Lighting Systems[17] <*Continued Operability Entity*>	When required, lights and lighting systems must be installed on and in the UAS payloads under consideration and must be designed and constructed, or selected from existing products, to be appropriate for the payload types under consideration. The lights and lighting systems must be described in terms of their characteristics, functions, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the lights and lighting systems remain operable under all anticipated operating conditions. New light and lighting system designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Compliance with relevant regulatory requirements regarding lights and lighting systems must also be demonstrated and reported.

C-7.6.5 Section: Miscellaneous Equipment

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Instruments and Equipment	Miscellaneous Equipment	General

This section provides information and details regarding miscellaneous equipment installed in the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[17,25] *<Continued Operability Entity>*	When required for the UAS payload under consideration, any functional or safety significant equipment not addressed elsewhere in this framework, must be designed and constructed, or selected from existing products, to be appropriate for the payload type under consideration. The equipment must be described in terms of their characteristics, functions, performance, interfaces, minimum operability capabilities and their continued operability requirements. Procedures, precautions and limitations must be identified to ensure that the equipment remain operable under all anticipated operating conditions. New equipment designs must be subjected to an appropriate engineering analysis, design and test process, from which inspection and maintenance programmes must be derived to ensure continued operability. Where applicable, compliance with relevant regulatory requirements regarding the equipment must also be demonstrated and reported.

C-7.7 Sub-Part: Operating Limitations, Safety Information and System Manuals

This sub-part must contain details of, and provisions for, operating limitations and safety information relevant to the UAS payloads under consideration. This sub-part must also describe and reference the system manuals for the UAS payloads under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manuals	Operating Limitations	General
		Markings and Placards	General
		System Manuals	General

The criteria relevant to the sections of this sub-part are presented in the following paragraphs.

C-7.7.1 Section: Operating Limitations

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manuals	Operating Limitations	General

This section provides information and details of operating limitations relevant to the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	For each UAS payload type under consideration, the operating precautions and limitations identified under each relevant section and sub-section of this Part IIID of the framework, and any other relevant operating limitations, must be consolidated and listed in an appropriate payload operating limitations reference document. The operating limitations reference document must be under configuration control. The operating precautions and limitations must also be included in the system manual for the UAS aircraft under consideration. Compliance with relevant regulatory requirements regarding the documentation of operating limitations must be demonstrated and reported.

C-7.7.2 Section: Markings and Placards

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manuals	Markings and Placards	General

This section provides details regarding operating and safety markings and placards applicable to the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	Appropriate operating and safety markings and placards to be installed in or on the UAS payloads under consideration must be identified, designed and described in terms of their characteristics, contents, functions, installation details and their continued operability (maintenance) requirements. Compliance with relevant regulatory requirements regarding safety markings and placards must also be demonstrated and reported.

C-7.7.3 Section: System Manuals

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Operating Limitations, Safety Information and System Manuals	System Manuals	General

This section describes and references the system manuals for the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	For each UAS payload type under consideration, the relevant system, sub-system and component information identified under each applicable section and sub-section of this Part IIID of the framework, must be consolidated and captured in an appropriate manner in a payload system manual. The system manual, which may consist of one or more parts, must be under configuration control and emphasis should be placed on the following: - descriptions; - performance details; - operating precautions and limitations; - continued operability requirements; - data and information required by relevant regulations; and - any other data or information required to achieve and maintain operability of the UAS payload. Compliance with relevant regulatory requirements regarding the contents of the system manual must be demonstrated and reported.

C-7.8 Sub-Part: Continued Operability

This sub-part must identify the continued operability requirements for the UAS payloads under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Continued Operability	Continued Operability Requirements	General

The criteria relevant to this sub-part are presented in the following paragraph.

C-7.8.1 Section: Continued Operability Requirements

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Continued Operability	Continued Operability Requirements	General

This section provides information and details regarding the continued operability requirements for the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[17] *<Continued Operability Entity>*	For each UAS payload type under consideration, the continued operability requirements identified under each relevant section and sub-section of this Part IIID of the framework, and any other relevant continued operability requirements, must be consolidated and listed in an appropriate payload continued operability reference document. This continued operability reference document must be under configuration control. The continued operability requirements must also be included in the system manual for the UAS aircraft under consideration. Compliance with relevant regulatory requirements regarding instructions for continued payload operability and aircraft airworthiness must be demonstrated and reported.

C-7.9 Sub-Part: Security

This sub-part must contain details of, and provisions for, appropriate security measures for the UAS payloads under consideration.

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Security	Payload Security	General

The criteria relevant to this sub-part are presented in the following paragraph.

C-7.9.1 Section: Payload Security

PART	SUB-PART	SECTION	SUB-SECTION
UAS OPERABILITY FRAMEWORK PART IIID - PAYLOAD OPERABILITY CRITERIA			
	Security	Payload Security	General

This section provides information and details regarding appropriate security measures for the UAS payloads under consideration. The criteria listed in the table below should be tailored and expanded as appropriate for the respective UAS payloads.

SUB-SECTION	OPERABILITY CRITERIA
General[4,49] <*Continued Operability Entity*>	Security risks associated with the UAS payloads under consideration must be established and appropriate security measures must be developed, implemented and regularly updated to secure the payloads against unlawful or malicious interference or use. Risks to be considered include at least the following: - vulnerability of communication and data links[4]; - interception/hijacking of the payloads for terrorist attacks[4]; - confidentiality of operations[49]; and - security of payloads during operations, transportation and storage. The risks and the security measures must be reviewed continuously in respect of new security risks and threats, in order to update the security measures on a regular basis. Compliance with relevant regulatory requirements regarding UAS security measures must be demonstrated and reported.

REFERENCES USED IN APPENDICES

1 Maneschijn, A., Jones, T., von Backström, T.W. and Ingham, L.A. A Proposed Reference Framework for Unmanned Aerial Vehicle and System Airworthiness Requirements. The Aeronautical Journal. Volume 111. Number 1120. London, Great Britain. 2007.

2 EASA. Advance-Notice of Proposed Amendment: Ref. A-NPA No. 16/2005. Policy for Unmanned Aerial Vehicle (UAV) Certification. Rulemaking Directorate, European Aviation Safety Agency. Köln, Germany. 2005.

3 USA FAA. Interim Operational Approval Guidance 08-01, Unmanned Aircraft Systems Operations in the U.S. National Airspace System. Unmanned Aircraft Program Office (AIR-160), Federal Aviation Administration. Washington, United States of America. 2008.

4 JAA/EUROCONTROL. The Joint JAA/EUROCONTROL Initiative on UAVs. UAV TASK-FORCE Final Report. Joint Aviation Authorities. Amsterdam, Netherlands. 2004.

5 USA FAA. Guide to Commercial Reusable Launch Vehicle Operations and Maintenance Version 1.0, March 2005. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2005.

6 USA FAA. Federal Aviation Regulations Title 14: Aeronautics and Space, Part 1 - Definitions and Abbreviations. Federal Aviation Administration. Washington, United States of America. 2009.

7 JAA. Joint Aviation Requirements JAR-1, Definitions and Abbreviations. Change 5, 15 July 1996. Joint Aviation Authorities Committee, Joint Aviation Authorities. Amsterdam, Netherlands. 1996.

8 EASA. CS-Definitions, Definitions and Abbreviations Used in Certification Specifications for Products, Parts and Appliances. ED Decision 2003/11/RM, 5 November 2003. European Aviation Safety Agency. Brussels, Belgium. 2003.

9 ICAO. Annex 8 to the Convention on International Civil Aviation: Airworthiness of Aircraft. Ninth Edition. International Civil Aviation Organization. Montréal, Canada. 2001.

10 ICAO. Airworthiness Manual. First Edition. Doc. 9760. International Civil Aviation Organization. Montréal, Canada. 2001.

11 USA FAA. Airworthiness Certification of Unmanned Aircraft Systems. Draft Order 8130.UAS. Federal Aviation Administration. Washington, United States of America. 2008.

12 Ingham, L.A. Considerations for a Roadmap for the Operation of Unmanned Aerial Vehicles (UAV) in South African Airspace. PhD Thesis. Stellenbosch University, South Africa. 2008.

13 National (SA) UAS Policy Co-ordination Committee (Airworthiness Sub-committee) and Maneschijn, A. Interim Policy for Civil Unmanned Aircraft Systems in South Africa. SA CARCOM and SA Civil Aviation Authority. Johannesburg, South Africa. 2008.

14 ICAO. ICAO Exploratory Meeting on Unmanned Aerial Vehicles (UAVs), Montréal, Canada, 23 - 24 May 2006. Summary of Discussions, ICAO-UAV WP/2. Montréal, Canada. 2006.

15 NATO. Ratification of Draft STANAG 4671 on Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR). NATO Joint Capability Group on Unmanned Aerial Vehicles (JCGUAV). Doc. PFP(NNAG-JCGUAV)D(2007)0002, 9 May 2007. Brussels, Belgium. 2007.

16 Haddon, D.R. and Whittaker, C.J. UK-CAA Policy for Light UAV Systems. Design & Production Standards Division, Civil Aviation Authority, Great Britain. 2004.

17 USAR Working Group (2004). UAV Systems Airworthiness Requirements (USAR). Version 3.0, 20 January 2005. UAV Flight Test Team Manager, Délégation Générale des Armements (DGA). Istres, France. 2005.

18 ICAO. Convention on International Civil Aviation. Document 7300/9. International Civil Aviation Organization. Montréal, Canada. 2006.

19 CASA. Civil Aviation Safety Regulations 1998 (Consolidation, including amendments up to 25 July 2007). Part 21, Certification and Airworthiness Requirements for Aircraft and Parts. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2007.

20 Maneschijn, A. Developing a Feasible Engineering Policy to Ensure Continued Aviation Safety in the South African Air Force. M.Sc. (Aero.Eng.) Dissertation. University of the Witwatersrand. Johannesburg, South Africa. 2002.

21 Military Flight Safety Inspectorate (FLYGI). Rules of Military Aviation (RML). Issue 2, 26 September 2000. Swedish Armed Forces. Sweden. 2000.

22 Chief of the Defence Staff. Technical Airworthiness Manual (TAM). Doc. C-05-005-001/AG-001 Change 4, 31 January 2006. Canadian Department of National Defence. Ontario, Canada. 2006.

23 Air Marshal. ADF Airworthiness Manual. Australian Air Publication 7001.048(AM1), 5 April 2001. Airworthiness Authority, Australian Defence Force. Australia. 2001.

24 Beek, C.Z.A. Aviation Legislation in South Africa, Volume 2: Civil Aviation Regulations, 1997. Service Issue 20, December 2008. LexisNexis. Durban, South Africa. 2008.

25 RTI International Center for Aerospace Technology. Reusable Launch Vehicles Operations and Maintenance Top-Down Analysis - Final Technical Report. RTI Report No. RTI/ 08087.002/Task 1.5-01F, 20 December 2002. Florida, United States of America. 2002.

26 Evans, AR. The Hazards of Unmanned Air Vehicle Integration into Unsegregated Airspace. M.Sc. (Safety Critical Systems Engineering) Research Report. September 2006. University of York. York, Great Britain. 2006.

27 CASA. Civil Aviation Safety Regulations 1998. Consolidation, including amendments up to 25 July 2007. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2007.

28 National Archives and Records Administration. Electronic Code of Federal Regulations (e-CFR), Title 14 - Aeronautics and Space, Chapter 1. United States

of America. Federal Aviation Administration. http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?&c=ecfr&tpl=/ecfrbrowse/Title14/14tab_02.tpl. Cited 3 October 2009.

29 Parametric Technology Corporation (PTC). White Paper: Total Lifecycle Systems Management (TLCSM). Overcoming the Achilles Heel in Today's Aerospace and Defense (A&D) Weapon Systems Development. Report 4172-A&D-WP-0109. Massachusetts, United States of America. January 2009.

30 Dahmann, J., Lane, J.A., Rebovich Jr, G., Baldwin, K.J. A Model of Systems Engineering in a System of Systems Context. Paper 215, 6th Annual Conference on Systems Engineering Research. California, United States of America. 2008.

31 Wikipedia Contributors. 'Systems Engineering Process'. Wikipedia, The Free Encyclopedia. http://en.wikipedia.org/w/index.php?title=Systems_engineering_process&oldid=339443754. Cited 23 March 2010.

32 Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering. Systems Engineering Guide for Systems of Systems, Version 1.0. Washington DC, United States of America. 2008.

33 Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering. Systems and Software Engineering: Defense Acquisition Program Support (DAPS) Methodology Version 2.0 Washington DC, United States of America. 2009.

34 Atkinson, C. et al. Framework for the Application of Systems Engineering in the Commercial Aircraft Domain. Draft Version 1.2a, 28 July 2000. Joint Commercial Aircraft Working Group, International Council on Systems Engineering (INCOSE). San Diego, United States of America. 2000.

35 Defense Acquisition University. Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System Wallchart. Version 5.3.4, June 2009. OP-CL Publications/Distribution, Defense Acquisition University. http://acc.dau.mil/IFC/index.htm. Fort Belvoir, United States of America. 2009.

36 Defense Acquisition University. Defense Acquisition Guidebook, 19 February 2010. Defense Acquisition University. https://dag.dau.mil. Fort Belvoir, United States of America. Cited 23 March 2010.

37 Pennell, LW and Knight FL. Systems Engineering. Draft Military Standard Mil-Std-499C, 15 April 2005. The Aerospace Corporation, Report No. TOR-2005(8583)-3. California, USA. http://www.everyspec.com/MIL-STD/MIL-STD+(0300+-+0499)/MIL-STD-499C_(DRAFT)_3775/. California, United States of America. Cited 23 March 2010.

38 Nowlan, F.S. and Heap, H.F. Reliability-Centred Maintenance. Report No. A066-579. United Airlines. San Francisco, United States of America. 1978.

39 USA FAA. Instructions for Continued Airworthiness: Responsibilities, Requirements, and Contents. Order 8110.54, July 2005. Federal Aviation Administration. Washington, United States of America. 2005.

40 Air Transport Association of America (ATA). MSG-3: Operator/Manufacturer Scheduled Maintenance Development. ATA Publications Department. Rev. 2005.1. Washington, United States of America. 2005.

41 Transport Canada. Civil Aviation Scheduled Maintenance Instruction Development Processes Manual. TP 13850E. Transport Canada Civil Aviation Communications Centre (AARC). Ottawa, Canada. 2005.

42 UK Ministry of Defence. JSP553, Military Airworthiness Regulations (2006) Edition 1 Change 5. http://en.wikipedia.org/wiki/Airworthy. Cited 3 September 2008.

43 Chief of Staff. Aviation Unmanned Aerial Vehicle Flight Regulations. Army Regulation 95–23, 14 May 2004. Department of the Army, United States Army. Washington, United States of America. 2004.

44 US Navy. Management Manual Guidelines for the Naval Aviation Reliability-Centered Maintenance Process. Navair 00-25-403, 1 July 2005. Naval Air Systems Command, US Navy. United States of America. 2005.

45 RTI International Center for Aerospace Technology. Reusable Launch Vehicle Operations and Maintenance Guideline Inputs and Technical Evaluation Report:

Maintenance - Volume 3, Final Report. RTI Report No. RTI/ 08087/007/1.2-Vol3F, 18 November 2004. Florida, United States of America. 2004.

46 DeGarmo, MT. Issues Concerning Integration of Unmanned Aerial Vehicles in Civil Airspace. Report MP 04W0000323, November 2004. Center for Advanced Aviation System Development, The MITRE Corporation. Virginia, United States of America. 2004.

47 US Air Force. SMC Systems Engineering Primer & Handbook. 3rd Edition, 29 April 2005. Space & Missile Systems Center, U.S. Air Force. United States of America. 2005.

48 Dalamagkidis, K., Valavanis, K. P. and Piegl, L. A. Current Status and Future Perspectives for Unmanned Aircraft System Operations in the US. Journal of Intelligent and Robotic Systems (Online), Ref. DOI 10.1007/s10846-008-9213-x. Springer Science and Business Media BV, Netherlands. 2008.

49 UK CAA. CAP 722 - Guidance for Unmanned Aerial Vehicle (UAV) Operations in UK Airspace. 2nd Edition. Directorate of Airspace Policy, UK Civil Aviation Authority. London, Great Britain. 2004.

50 Rehn, T. Swedish Armed Forces' UAV System Vision for Operation in Non-Segregated Airspace. Issue 2, Enclosure 1 to HKV 29 Nov 2004, 29 November 2004. Doc. Ref. 02 810:77056. Swedish Armed Forces Headquarters, Swedish Armed Forces. Sweden. 2004.

51 NASA. NASA Procedural Requirements: Systems Engineering Processes and Requirements. NPR 7123.1A, 26 March 2007. Office of the Chief Engineer, NASA. United States of America. 2007.

52 USA FAA. Reusable Launch and Reentry Vehicle System Safety Process. Advisory Circular AC No. 431.35-2A, 20 July 2005. Office of Commercial Space Transportation, Federal Aviation Administration. Washington, United States of America. 2005.

53 CASA. UAV Design Standards - Rotorcraft (Draft). Version 2.2, 26 May 2000. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2000.

54 Joint Airworthiness Committee - UAV System Sub Committee. Design and Airworthiness Requirements for Service Aircraft - UAV Systems. Defence Standard 00-970 Part 9. Issue 4, 27 January 2006. Defence Procurement Agency, Ministry of Defence. Bristol, Great Britain. 2006.

55 CASA. Unmanned Aircraft and Rockets: Unmanned Aerial Vehicle (UAV) Operations, Design Specification, Maintenance and Training of Human Resources. AC 101-1(0), July 2002. Legislative Drafting Branch, Legal Services Group, Civil Aviation Safety Authority. Canberra, Australia. 2002.

56 EASA. CS-29, Certification Specifications for Large Rotorcraft. ED Decision 2003/16/RM, 14 November 2003. European Aviation Safety Agency. Brussels, Belgium. 2003.

57 Haddon, D.R. and Whittaker, C.J. Aircraft Airworthiness Certification Standards for Civil UAVs. The Aeronautical Journal. Volume 107, Number 1068. pp 79 - 86. London, Great Britain. 2003.