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A Systems Approach to Compliance with Australian Airworthiness Regulations for Uninhabited Aircraft Systems

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A Systems Approach to Compliance with Australian Airworthiness Regulations for Uninhabited Aircraft Systems

A thesis submitted in fulfilment of the requirements for
the degree of Master of Engineering

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; and, any editorial work, paid or unpaid, carried out by a third party is acknowledged.

Anthony Schnellbeck
March 2006

Acknowledgement

I would like to thank my supervisor, Dr Cees Bil, and the many colleagues, friends and family members for their advice, patience and encouragement during the time over which this work has developed.

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Summary

A considerable amount of research effort has, and continues to be invested into technologies and algorithms for capabilities which are forecast to be needed in future uninhabited vehicles. Much of this research is conducted with the aim of increasing the level of autonomy of these vehicles. However these technologies and capabilities provide only a part of the total system solution and must be integrated into an architecture that covers the entire vehicle system. This total system approach is particularly relevant since this is how airworthiness regulators consider Uninhabited Aircraft Systems.

Airworthiness of uninhabited aircraft has been addressed by Australian aviation regulators. While the regulations may be in place, technical challenges still remain for the suppliers of these systems. For example, one of these unresolved technical challenges is the capability of uninhabited aircraft to “see and avoid” other aircraft. The operation of manned and uninhabited aircraft in the same airspace remains an issue and certification of uninhabited aircraft for unrestricted operations remains a challenge.

The work described here has used the systems engineering approach to develop a high level architecture for a generic Uninhabited Aircraft System. The architecture was derived from airworthiness regulations. Since the primary difference between piloted and uninhabited aircraft is the presence of an on-board human pilot, this is the main area which this architecture describes.

Australian airworthiness regulations were taken as the starting point to provide requirements. This ensured that the statutory requirements were considered in the

development of the architecture. The requirements and functional analysis techniques from systems engineering were applied to the airworthiness regulations. This produced a set of derived requirements and a functional description of the UAS. The requirements analysis results in a “black box” or external description of the necessary properties and qualities of the system. Functional analysis produces a “white box” or internal description of the workings of the system which allows decomposition into smaller elements.

The requirements and functional description which have been developed are generic and are applicable to many Uninhabited Aircraft Systems. The resultant architecture may be used in conjunction with operational requirements to develop a specific Uninhabited Aircraft System. Since the architecture is generic, it may also be used to provide the structure of a simulation model of an Uninhabited Aircraft System.

Abbreviations and Acronyms

3D	Three Dimensional
ADS	Automatic Dependent Surveillance
ADT	Air Data Terminal
AGARD	Advisory Group for Aerospace Research and Development
AI	Artificial Intelligence
AIAA	American Institute of Aeronautics and Astronautics
ATC	Air Traffic Control
AV	Air Vehicle
AVS	Air Vehicle Subsystem
BIT	Built In Test
C2	Command and Control
CASA	Civil Aviation Safety Authority
DEF STAN	Defence Standard
DLS	Data Link Subsystem
DSTO	Defence Science and Technology Organisation
EMI	Electromagnetic Interference

FT	Flight Termination
GCS	Ground Control System
GDT	Ground Data Terminal
HALE	High Altitude Long Endurance
IEEE	Institute of Electrical and Electronics Engineers
KBS	Knowledge Based System
L&R	Launch and Recovery
LOS	Line Of Sight
MIL-STD	Military Standard
MIT	Massachusetts Institute of Technology
MoD	Ministry of Defence (UK)
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organisation
OR	Operations Research
OSD	Office of the Secretary of Defense
PBS	Product Breakdown Structure
RF	Radio Frequency
RFA	Request For Approval

RPM	Revolutions Per Minute
RPV	Remotely Piloted Vehicle
RTO	Research and Technology Organisation (NATO)
SSR	Secondary Surveillance Radar
STANAG	Standardisation Agreement
UAV	Uninhabited Aerial Vehicle
UAS	Uninhabited Aircraft System
UCAR	Unmanned Combat Armed Rotorcraft
UCAV	Unmanned Combat Aerial Vehicle
UK	United Kingdom
US	United States (of America)
WBS	Work Breakdown Structure

CHAPTER 1 INTRODUCTION

1.1 Background

Uninhabited Aerial Vehicles (UAV) have been around since at least World War I (Siuru 1991) and have been employed by the armed forces of various nations in many major conflicts in the intervening period. However, it is only relatively recently that they have begun to receive wide-spread acceptance and increased use.

Many research papers and programs involve investigations into technologies and algorithms for capabilities that are forecast to be needed in future uninhabited vehicles. Much of this research is conducted with the aim of increasing the level of autonomy of these vehicles. However all of these technologies and capabilities provide only a part of the total system solution and must be integrated into an architecture that covers the entire vehicle system.

1.2 Overview

This thesis provides one such architecture. The systems engineering process was used to develop a functional description of a generic Uninhabited Aircraft System (UAS). A UAS contains both a UAV and a ground segment, which provides the interface to the human operator, allowing command and control (C2) of the system.

Airworthiness regulations were taken as the starting point to provide requirements. This ensures that the resulting functional description accommodates the requirements of the mandatory airworthiness regulations. Requirements analysis was conducted to identify the functions which must be performed to satisfy compliance.

Functional analysis was then conducted to identify the implicit functions and develop a functional hierarchy.

Since the functional description is generic, it may provide a framework for the integration of many specialised technologies. One such technology is integrated flight and payload control. This provides the capability to integrate air vehicle flight and payload control, providing a system that can maintain payload pointing through a combination of payload steering demands and aircraft flight control surface demands.

The requirements and functional description are generic and may be applied to specific UAS in conjunction with detailed operational requirements and the payloads needed to accomplish a particular mission.

1.3 Aim of the Research

The aim of this research is to develop a high-level functional description for a generic UAS.

The functional description will be derived from Australian civil airworthiness regulations. This will ensure that the mandatory requirements are considered during the system development.

The functional description should be generic so that it is widely applicable and able to form the basis of future developments.

The architecture should allow the integration of specialised aviation and UAS specific technologies.

1.4 Thesis Overview

This chapter has provided an introduction to the subject of the research reported in this thesis. The remaining chapters expand on this introduction and provide more detail and the results of the research which has been undertaken.

CHAPTER 2 contains the literature review. The published engineering literature was searched for similar work. The results of this search are presented.

CHAPTER 3 provides an overview of the systems engineering process as applicable to the work described in this thesis. The relevant aspects of systems engineering are the analysis of requirements and functionality. There are many other aspects of systems engineering which are not discussed since they are not necessary for the development of a generic functional description.

CHAPTER 4 describes the analysis of the system level requirements. Australian airworthiness regulations were used as the system level requirements.

CHAPTER 5 describes the analysis of the system level functionality. This analysis identified the implicit functionality in the system.

CHAPTER 6 describes the analysis at the subsystem level which followed the system level analysis.

CHAPTER 7 contains a discussion of problems and observations noted during the research.

CHAPTER 8 is the summary and concluding remarks.

CHAPTER 9 contains the list of references.

Appendix One (CHAPTER 10) contains the results of the system level requirements analysis process.

Appendix Two (CHAPTER 11) contains the data dictionary tables.

Appendix Three (CHAPTER 12) contains the results of the functional analysis at the system level.

Appendix Four (CHAPTER 13) contains the function hierarchy diagrams.

Appendix Five (CHAPTER 14) contains the functional flow diagrams.

Appendix Six (CHAPTER 15) contains the functional requirements and functional allocation at the subsystem level.

CHAPTER 2 LITERATURE REVIEW

2.1 A Brief History of UAV Use

UAVs have been used for military purposes since at least World War I (Siuru 1991). Munson (1988) described over 320 different UAVs, many of which have numerous variants and derivatives, developed by companies and organisations from all around the world. For much of their history, the use of UAVs has been dominated by military applications. Current UAS, and forecasts of the systems, employment and technology expected to be used by the US armed forces are described in US Department of Defense documents (OSD 2002; OSD 2005; Office of the Under Secretary of Defense for Acquisition, Technology and Logistics 2004). Although military forces are still the main operators of UAS, in recent decades there has been a growing recognition of the potential for civilian and research applications all around the world.

2.2 UAV Activity and Applications

Wilson (2003) presented a perspective on world wide UAV activity. At the time of his article, at least 36 countries were actively involved in either development or acquisition programs for UAVs. The most active countries included the UK (18 programs), France (over 24 programs), Russia (18 programs), Israel (20 programs), Turkey (at least six programs) and the USA with at least 60 military programs. Defence spending in the US on UAV programs during the 2002 fiscal year was $US716 million. The approved budget for UAV programs in the 2003 fiscal year was $US1.2 billion with forecast budget requests of $US1.4 billion and almost $US2 billion in fiscal years 2004 and 2005 respectively.

In Australia during 2002, there were at least seven UAV development programs with civilian, military and research applications (staff writers & Blackman 2002). La

Franchi (2005) described the range of activity and the level of interest in UAVs in the Australian defence community. The need for an integrated and coordinated approach to the development of a UAV capability and acquisition of systems was emphasised.

Wegener et al. (2004) described the use of autonomous heterogenous multiple UAV systems for Earth science and monitoring applications. An architecture for autonomy was presented. Various civilian mission concepts for UAVs were discussed along with the benefits to be gained from levels of autonomy above that currently available. Krabill (2005) describes the potential use of UAVs for science applications over ice sheets and glaciers in the Arctic and Antarctic. These applications included measurement of glaciological parameters (surface elevation, ice velocity, ice thickness and surface melt detection), mapping bedrock topography, investigation of melt ponds on sea ice and measurement of the depth of snow cover on sea ice. Horcher and Visser (2004) present the results of a trial application of UAV technology to forestry management. A small UAV was used to provide both still and video imagery of research sites in a national park for mapping and monitoring purposes. The potential applications included monitoring for water quality violations, detection of timber theft, detection of erosion in road and drainage networks, and the detection of trespass and other illegal activities. Srinivasan et al. (2004) describe the use of an Airborne Traffic Surveillance System which includes UAVs for the monitoring of highways and traffic conditions. This work was conducted by the University of Florida in conjunction with the Florida Department of Transportaation. Work is also progressing on the consideration of business models for the delivery of UAV services to support science applications (NASA Suborbital Science Office 2004).

The preceding summary provides a very high level introduction to the level of UAV and UAS activity and the range of potential applications for these systems. If UAVs are employed for even a number of these applications then the level of unmanned systems activity will increase considerably. The technical challenges involved in developing UAS for these applications are generally manageable. The main challenge lies in the airworthiness of UAS and their operation in civil airspace.

2.3 Airworthiness Certification of UAS

Widespread use of UAS, outside restricted airspace, including possibly over populated areas, will require civil airworthiness certification. The Australian Civil Aviation Safety Authority (CASA) has published airworthiness regulations specifically for UAS (CASA 2002). These regulations cover the design, maintenance and operation of UAS and the training of operators. Papachristofilou, Kaempf and Wagner (1997) discuss the requirements and design of a UAV system for certification and flight in civil airspace. Given that at the time of writing, no specific regulations existed, the authors adopted civil airworthiness principles. These included the probability of a third-party fatality (less than 10^{-9} per flight hour as a result of any failure) and that there should be no discernible difference between manned and unmanned aircraft from the perspective of Air Traffic Control authorities. Rogers (2000) considers the safety and airworthiness of a UAV system, from the UK perspective, and the general requirements which flow into the system specifications. The military perspective of safety and airworthiness is discussed in detail. The development of Part 9 of DEF STAN 00-970 (MoD 2003) which is the UK military standard for airworthiness of UAS is discussed. Haddon and Whittaker (2003) describe the considerations and method of developing civil airworthiness requirements for UAS in the UK. These authors work in the UK Civil Aviation Authority. Their paper presents the CAA position regarding the design standards to be applied for civil certification of UAS. From the US, the HALE UAV Certification & Regulatory Roadmap (NASA ERAST Alliance n.d.) describes proposed airworthiness requirements for a High Altitude Long Endurance (HALE) UAV. These US requirements appear similar to the Australian CASA requirements. Papers by Weibel and Hansman (2005) and DeGarmo and Nelson (2004) both discuss considerations, including safety, for the operation of UAS in the US National Airspace System.

Airworthiness authorities consider each UAS in its entirety. The ground-based elements are a part of the system and have an effect on airworthiness. An organisation seeking to obtain certification for an uninhabited air vehicle must therefore consider the whole system; the UAS rather than only the UAV. Cameron (1995) and Fahlstrom and Gleason (1992) are two sources which provide an overview of the elements of a UAS. Scheithauer and Wunderlich (1997) consider the architecture of a UAS from a system integrity perspective. This paper considers military systems and includes aspects not relevant to civil systems such as hostile threats. The authors conclude that system architectures, design methods and verification methods must be developed to provide cost-effective high integrity systems. White (2003) treats an Uninhabited Combat Air Vehicle (UCAV) as a system and considers the integration of the human element. This paper presents a variable autonomy system which provides varying levels of support to the human operator depending upon task and workload. An allocation of functionality between the operator and the computer system is proposed. The author concludes by presenting a staged introduction of autonomy into unmanned systems.

The airworthiness certification of UAS and their operation in civil airspace pose challenges. The above references provide an overview of these challenges and some proposed responses. A rigorous systems engineering process will assist in meeting these challenges and must be part of the response.

2.4 Systems Engineering

Engineering Management (1974) defines systems engineering as "A logical sequence of activities and decisions transforming an operational need into a description of system performance parameters and a preferred system configuration". This reference is a military standard describing the process of systems engineering. An equivalent and more recent civilian standard is *Processes for Engineering a System* (1999).

There are a number of handbooks describing in more detail how to apply the process. Many large organisations produce their own handbooks describing how the process is to be applied in that organisation. An example from the US Department of Defense is *Systems Engineering Fundamentals* (1999). Examples produced by civilian agencies include those by the European Space Agency (*Space Engineering: System Engineering* 1996) and NASA (1995). Text books on the subject of systems engineering are also available; one example of which is by Blanchard and Fabrycky (1998).

The application of systems engineering methods ensures that the entire system is considered. Published examples of the application of the systems engineering process seem to be uncommon in the refereed technical literature. One example is Adams (1995), who presents an example of the functional decomposition process applied to a real-time planning and decision making system.

2.5 UAS Technology Trends

This section provides examples of technology developments which are applicable to UAS. None of these technologies will be discussed in detail. They are presented to provide an overview of the types of technologies which will need to be integrated into a complete UAS architecture.

The trend in military systems is towards increasing levels of autonomy, as discussed in OSD (2002) and OSD (2005). Robinson (2004) quotes that (in the context of the US Army's Unmanned Combat Armed Rotorcraft (UCAR) programme) the goal is to eliminate the 'vigilant monitoring' needed for current UAVs.

There are a number of aspects to the problem of autonomy. Some of these aspects include decision making, path planning and re-planning, cooperation with other autonomous vehicles and collision avoidance. Gancet et al. (2005) present an architecture for decision making in a heterogenous multiple UAV system. Both the ground and air elements of the system are considered and decision making may occur at different places in the system. Schiller and Draper (1991) developed a simulation using a neural network for UAV navigation in uncertain environments. The robustness of the neural network re-planner improved the probability of mission success. Other path planning research is presented by Schouwenaars et al. (2004), Jenkins (1987) and Zheng, Ding and Zhou (2003). Two approaches to path planning for multiple vehicles are presented by McInnes (2003) and Pongpunwattana and Rysdyk (2004). Rathinam et al. (2004) presents an architecture for controlling a team of UAVs to search for targets in a given region. Penney (2005) presents a method for performing collision avoidance on autonomous UAVs.

One approach which has benefits both in increasing autonomy and in reducing operator workload is to integrate the control of the vehicle with the payload. Williams and Davidson (1991) developed an airborne re-planner which directs the aircraft to investigate targets found by the sensor. A real-time rule-based artificial intelligence (AI) component written in Forth was used to determine and execute actions based upon a database of rules. The re-planner was linked to the autopilot to command the aircraft. Johnson et al. (2004) describe the development and testing of a UAV with integrated flight and payload control. However in their case, the UAV was to be autonomous and so the ground element was not part of the integration. Kaminer et al. (1998) present a method for the design of integrated guidance and control systems for autonomous vehicles. Thomasson (1998) describes the integrated control of a roll-only camera in the nose of an aircraft when used for ground observation. Audenino, Gaglio and Faggion (1992) describe the procedures and techniques for automated target tracking and locating using a video payload on a tactical UAV.

These technologies must be implemented in the aircraft avionics and the ground segment electronics. Boskovic, Prasnath and Mehra (2004) present an avionics architecture which provides the capability for the UAV to detect and identify faults and failures and reconfigure control laws, react to new information such as pop-up targets, and autonomously re-plan the mission. However this work only considers the airborne element of the UAV system. Hitt (2004) discusses some considerations for the implementation of future avionics systems. This reference also considers the airborne element although many of the considerations apply to the ground element of a UAS. Rushby (1999) presents a study into partitioning in avionics architectures. Kirschbaum (2005) discusses STANAG 4586 which provides a standardised data link interface between ground and air segments. This is particularly important for interoperability between different systems.

None of the technologies mentioned above are covered here any further. The survey above serves to illustrate the breadth and variety of research into UAS technologies which is on-going. Very few of the papers reviewed above consider the technology in the context of a system. However, for use in an actual system, as opposed to a simulation, the technology must be integrated into the airborne segment, the ground segment or both.

The literature survey described above failed to find a significant number of references regarding the architecture of UAS. This is considered to be a problem given that the demand for these systems will continue to increase as further applications are found. It is, of course, possible that many UAS architectures have been developed but that these are proprietary and have not been released for public consideration.

The work presented in the following sections provides a high-level generic architecture for selected elements of a UAS into which different technologies, such as those described above, may be integrated.

CHAPTER 3 SYSTEMS ENGINEERING

3.1 Introduction to Systems Engineering

Much work has been done and much has been written on the subject of systems engineering. A small selection of works includes references by military agencies (*Engineering Management* 1974; *Systems Engineering Fundamentals* 1999), civilian agencies (ESA 1996; NASA 1995), industry standards bodies (*Processes for Engineering a System* 1999) and academic authors (Blanchard and Fabrycky 1998). Possibly as a result of the volume of material available, there is no universally accepted definition of systems engineering. Often, each reference will provide a different definition. However most definitions of systems engineering include the following key points:

- Delivers a solution to satisfy a customer's needs;
- Considers the entire lifecycle of the product or system;
- Is an interdisciplinary effort; and
- Involves an iterative process of refinement and definition starting from the top level requirements.

These points are explained in more detail below.

The primary purpose of systems engineering is to ensure that the system or product which is developed satisfies the needs of the customer. This is achieved through the activities in the systems engineering processes. The first activity occurs at the start of the development process, with the aim of identifying exactly what the customer needs the system to do and any constraints on the system. The result of this activity is expressed as a set of requirements for the system. Consequently, this activity is often called requirements development or analysis. Identifying what the customer needs may be a significant task in itself. For novel systems or when untried technology is involved, it may be necessary to include concept exploration and prototype development phases to identify requirements for the system.

Functional analysis is the activity which involves the decomposition of functionality. Implicit functionality is identified. Functions are grouped and allocated to subsystems or components.

The output of the requirements analysis and development activity provides the input to the design activity. Design produces a solution to the customer's need expressed as a set of requirements. Some iteration between the requirements analysis and design activities normally occurs. This takes account of the influence of the available technology and its cost on the requirements.

The final activity occurs at the end of the development process. This activity is called qualification and acceptance. This involves verifying that the system or product which has been developed meets the customer's needs as expressed in the requirements. This may be achieved through a variety of methods but testing is often involved.

Systems engineering considers the entire life cycle of the system or product under development. A typical product lifecycle is shown in Figure 1 below.

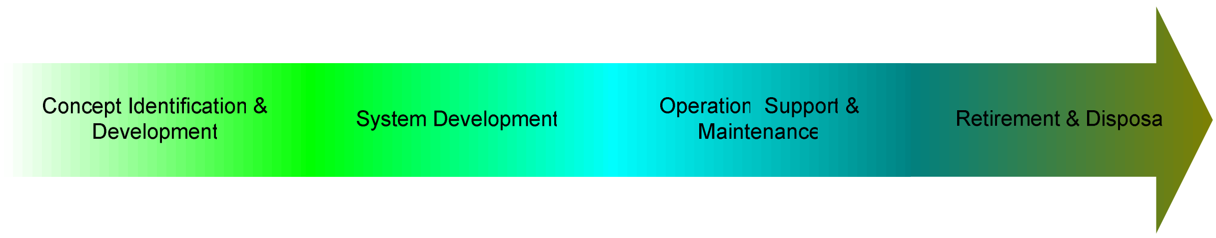

Figure 1. A Typical Product Lifecycle

Systems engineering facilitates the consideration of support, maintenance and disposal during the development phase. Early consideration of these additional aspects enables the developer to arrive at a solution with the lowest whole-of-life cost.

A thorough systems engineering process will ensure that all relevant disciplines have input during the development phase. These disciplines cover both the traditional and many specialist areas, including:

- Engineering (aeronautical, mechanical, electrical, electronic, software, chemical, civil, environmental, naval, biomedical, etc);
- Human factors and Usability;
- Availability and Reliability;
- Maintainability and Serviceability;
- Support (including Supply and Training) and Supportability;
- Vulnerability and Survivability;
- Affordability and Life-cycle costing;
- Interoperability;
- Produceability and Manufacturability; and
- other specialities as required.

Finally, systems engineering employs a process of decomposition and integration. A common view is the V diagram, shown in Figure 2.

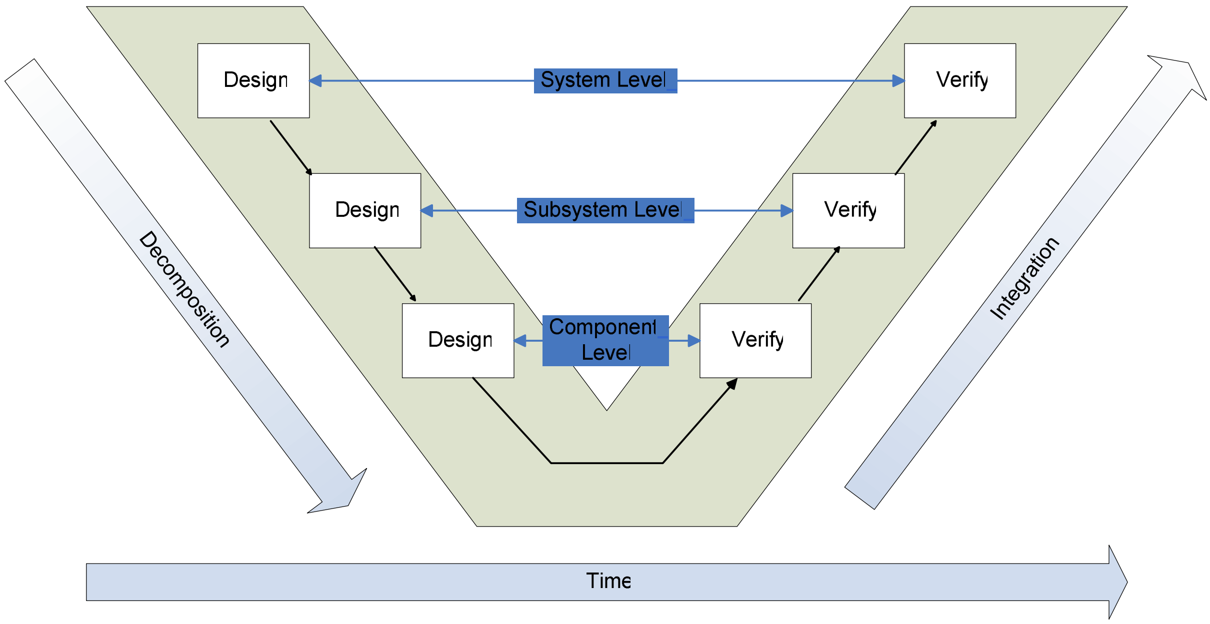

Figure 2. V Diagram Representation of System Engineering

The left arm of the V is the decomposition arm. Here the system design is broken down into increasingly smaller elements which can be individually managed and developed. Decomposition begins at the system level with the identification of subsystems and continues at the subsystem level with the identification of components. The subsystems and components which were identified are subsequently designed. The structure of the system after decomposition may look similar to Figure 3.

The right arm of the V is the integration arm. Integration is the activity which forms subsystems out of components and a system out of the subsystems. Integration begins at the component level by verifying that the components satisfy their requirements. The components are then integrated into subsystems which are verified against the subsystem requirements. Finally the subsystems are integrated into a system which is verified against the system level requirements. This ensures that the system satisfies the customer's needs. Complex systems may have properties which are not inherent in any of the subsystems or components but rather arise from the particular arrangement of those subsystems and components. These are called emergent properties. They may be either desirable or undesirable properties of a particular system. Integration should confirm the existence of desirable emergent properties and seek to identify any unexpected emergent properties.

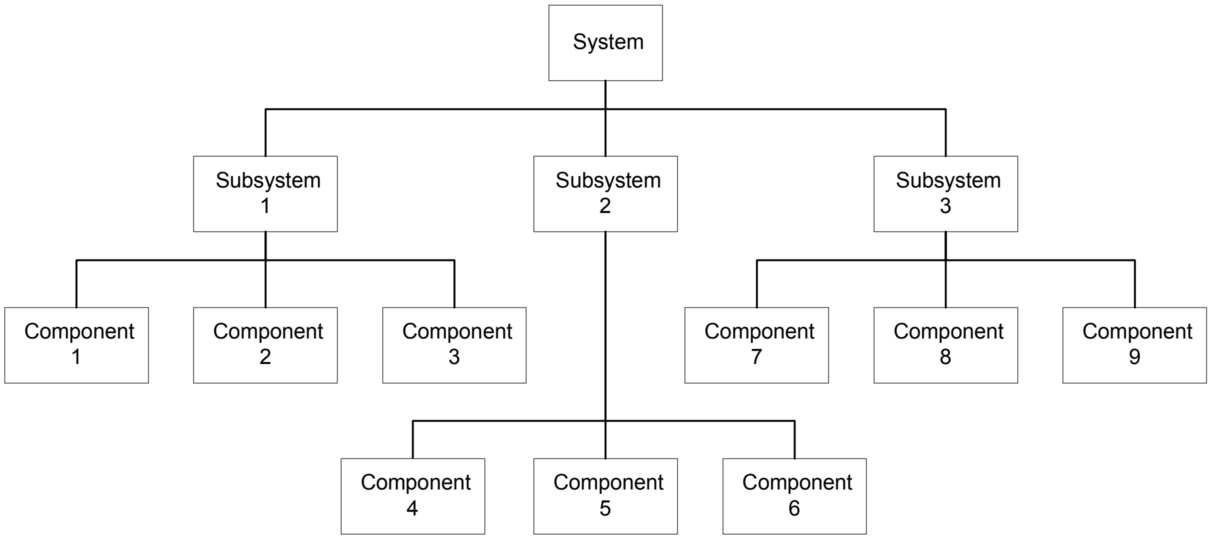

Figure 3. System Decomposition

The same system engineering process and activities occur at each of the system, subsystem and component levels.

Systems engineering is a multi-disciplinary process, which uses decomposition and integration, and which ensures that the product satisfies the needs of the customer throughout the entire lifecycle.

3.2 The Systems Engineering Process

The objectives and aspects of systems engineering described in Section 3.1 are implemented and achieved through the systems engineering process. This consists of a set of activities which result in the objectives discussed above being satisfied.

The systems engineering process mostly occurs within the development phase of the product lifecycle. A simplified view of the systems engineering process is shown in Figure 4.

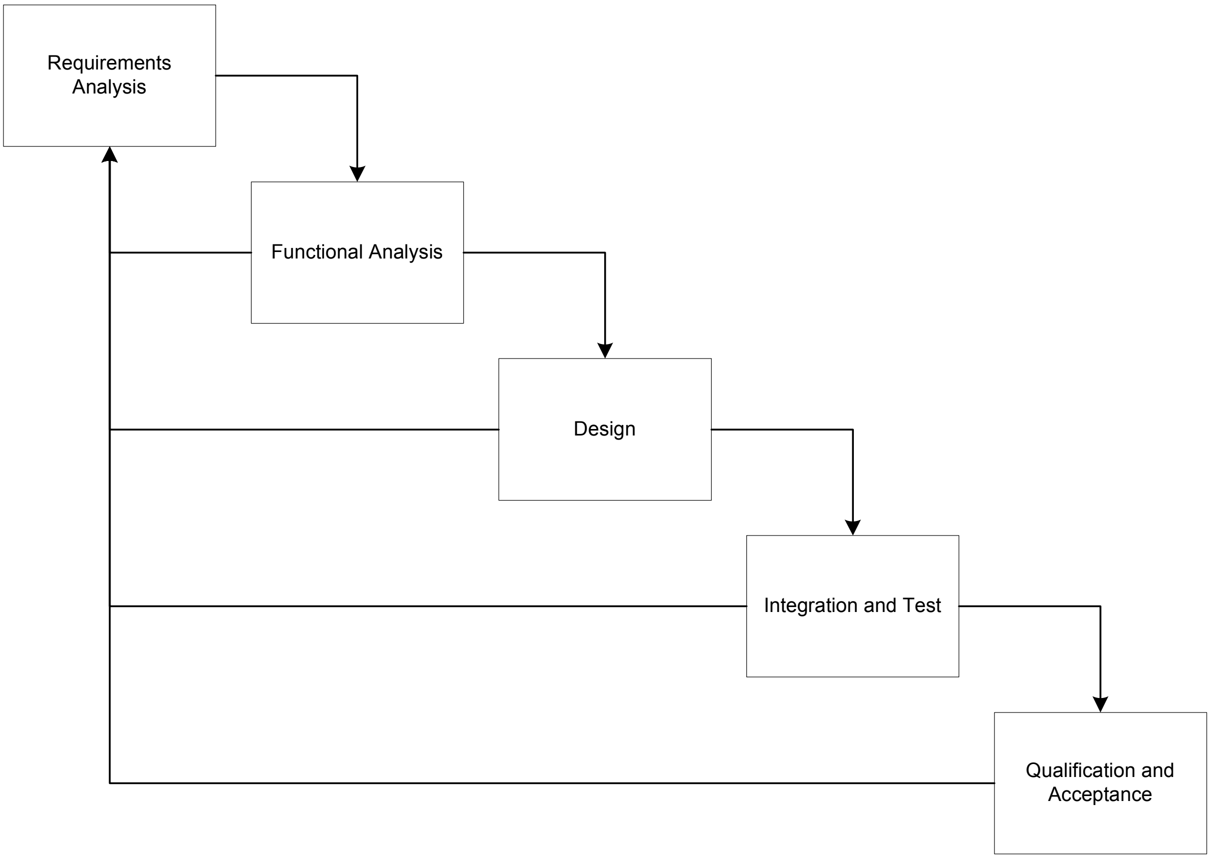

Figure 4. The Systems Engineering Process

Figure 4 shows a view of the process applied to a single element of a product with a simple “waterfall” lifecycle model. The waterfall model is a simple linear development path. Real systems are generally too complex for the waterfall model to be effective. Other lifecycle models are possible, such as rapid prototyping or the incremental development of the spiral model. A certain amount of iteration will be required to converge upon a solution. For complex systems, the systems engineering process is applied concurrently at all levels; system, subsystem and component; with information and feedback flowing between levels. Iteration is required not only in the systems engineering process at each level (requirements analysis, functional anaylsis, design, integration, test and verification) but also between the system, subsystem and component levels.

Following delivery of the system, the main activity is often maintenance, support and upgrades until the end of the lifecycle when disposal occurs.

Requirements analysis and functional analysis are the two stages in the process which are relevant to this work. An overview of these activities will be provided in the remainder of this chapter, with more details in the following chapters.

3.3 Systems Engineering Applicable to This Work

The aim of this work was to develop a generic high-level functional architecture for selected elements of a UAS. The term architecture is used to mean a representation of the structure of the system at a high level.

This research involves the application of systems engineering at both the system and subsystem levels. The research involves the first two steps of the systems engineering process in Figure 4; requirements analysis and functional analysis. The result of these two steps will be a set of requirements and a functional model of the generic UAS. The design step is not needed since the architecture is intended to be generic and abstract. The last two steps, integration and test, and qualification and acceptance, are also not required.

The methods of requirements analysis and functional analysis used the following steps:

(a) Analyse the requirements:

- (i) Generate a set of requirements from CASA airworthiness regulations;
- (ii) Maintain traceability back to CASA regulations;
- (iii) Identify requirements (as opposed to headings and explanatory notes);

(iv) Identify the type of each requirement;

(v) Draw the context diagram for the system;

(b) Perform functional analysis:

(i) Create a function for each functional requirement allocated to the Mission subsystem;

(ii) Construct a hierarchy of functions derived from the functional requirements;

(iii) Construct functional flow diagrams;

(iv) Logically group the functions in the hierarchy;

(v) Decompose the functional flows;

(vi) Create additional functions to produce a logical hierarchy and functional flows;

(vii) Iterate around these steps until the set of functions is complete and consistent;

(viii) Create data flow diagrams with the functions;

(ix) Create a data dictionary to document the functions and data flows;

(x) Iterate the functional hierarchy, functional flows and data flows until a complete and consistent set of functions and data flows is achieved;

(xi) Define a generic Product Breakdown Structure (PBS);

(c) Apply checks to requirements and functional analysis to ensure correctness, consistency and completeness.

These steps will be described in more detail in the following chapters. At the conclusion of these steps, a set of requirements and a generic functional architecture will have been produced.

3.4 Additional Functional Analysis for Specific System Designs

While the systems engineering steps described in section 3.3 are sufficient for the development of a generic functional architecture, additional steps are required for the development of the design of a specific physical system. These additional steps are:

(a) Logically group the functions which are similar and have similar interfaces;

(b) Add lower levels of detail to the PBS by creating new subsystems and components;

(c) Allocate functions to PBS subsystems and components; and

(d) Identify the major subsystem interfaces.

These steps are not required for the development of a generic functional architecture and will not be considered further.

CHAPTER 4 SYSTEM LEVEL REQUIREMENTS ANALYSIS

This chapter describes the analysis of the system level requirements. The purpose of this analysis was to identify the explicit functional requirements of the system.

4.1 The Requirements Analysis Process

The process of analysing the system level requirements consisted of the following steps:

(a) Format the airworthiness regulations (CASA 2002) for analysis;

(b) Maintain traceability back to the CASA regulations;

(c) Identify requirements (as opposed to non-requirements which include headings and explanatory notes); and

(d) Identify the type of each requirement.

These steps will be explained in more detail in the following sections.

4.2 Input Requirements

The top level system requirements were taken to be provided by the Australian UAS airworthiness regulations (CASA 2002). An extract of these regulations are provided at Table 1 in APPENDIX 1: REQUIREMENTS ANALYSIS OF AC101-1(0) (CHAPTER 10). The extract presented in Table 1 contains the requirements applicable to the operational elements of a UAS. The sections not included in the extract cover the requirements of the certification process and non-operational supporting functions such as training and maintenance. The sections of AC101-1(0) which are not included in Table 1 are:

- Section 9 Unmanned Aerial Vehicle Certification;

- Section 10 UAV System Maintenance;
- Section 11 Training Requirements for Pilots and Controllers of UAVs;
- Section 12 Getting Approval;
- Section 13 Operator Certification;
- Section 14 Insurance; and
- Appendices 1, 2 and 3.

Table 1 contains the text from the relevant sections of AC101-1(0) in column (c). The text was divided so that each heading, sentence and list element was in a separate table row.

Columns (b) and (a) of Table 1 contain the paragraph reference in AC101-1(0) and a unique requirement identifier respectively. The requirement identifier is prefixed with "C" (for CASA). Column (b) provides traceability from the system requirements back to the airworthiness regulations which state the statutory requirements. Maintaining traceability is important for a number of reasons. Firstly, it provides a means of ensuring that all system level requirements have been addressed. This directly supports the purpose of systems engineering. Secondly, any requirement which cannot be traced to a system level requirement or a design decision (for derived requirements) is unnecessary. This may indicate an error in the requirements derivation, or that the solution has 'gold-plating' (unnecessary additional functionality or features) or that there are unnecessary constraints on the design solution.

4.3 Requirements Analysis

An initial analysis of the contents of AC101-1(0) (as extracted in Table 1) was performed. This involved firstly, identifying which table rows contained requirements, and secondly, classifying the requirements for further analysis.

The text of each row in Table 1 was assessed as to whether it contained a requirement or not. Column (d) contains the results of this assessment. “TRUE” indicates that the text in column (c) is a requirement which must be complied with. “FALSE” indicates that the text is not a requirement. This is usually the case for headings and comments.

Each table row containing a requirement (i.e. where column (d) = TRUE) was then classified according to the type or types of requirements it contained. The possible types and their meanings are:

- Certification: a requirement which pertains to the CASA certification process or the products necessary to satisfy that process.
- Design Constraint: a requirement which constrains the design solution. For example a requirement which specifies the use of a particular item of equipment.
- Functional: a requirement which specifies some function (or action) which the system must perform.
- N/A: a requirement type is not applicable because the text is not a requirement.
- Operational: a requirement which specifies how the system should be operated or used.

- Performance: a requirement which specifies quantitatively how well a function must be performed.

- Safety: a requirement which specifies a safety related objective or constraint. These requirements are explicit inputs into a safety analysis process. The analysis of system safety will not be performed or discussed further in this thesis. The safety analysis would be expected to produce additional requirements derived from the safety requirements.

These requirement types are recorded in column (e) of Table 1.

Requirements propagate to the lower stages of system development. Functional requirement propagate through functional decomposition performed during functional analysis. Performance requirements propagate to subsystems through a budgeting and allocation process. Design constraints propagate either by direct assignment or by budgeting and allocation.

Requirements analysis is an iterative process. A requirement of one type may result in derived requirements of other types in later iterations of the analysis process. For example, design constraints, operational and safety requirements may result in derived functional requirements in later iterations. This may be especially true of safety requirements where the subsequent system safety analysis is likely to result in additional functional requirements necessary to provide a required level of safety.

The initial requirements analysis identified the rows in Table 1 containing requirements and classified those requirements according to type. The explicit functional requirements were identified.

4.4 System Context Diagram

The system requirements identify the external entities which have interfaces to the system. These entities interact with the system, usually by providing sources of data into the system or by acting as sinks for data output by the system. (A context diagram may also show the flow of energy and materials). A complete context diagram allows all of the external interfaces to the system to be identified. The context diagram for the UAS is shown in Figure 5.

The “Air Traffic Control”, “Other Aircraft” and “Operator” entities in the context diagram were identified from the system requirements in Table 1. The “Environment” entity has been included as a placeholder source for unspecified general signals from outside the UAS. The entities in the context diagram are defined in the data dictionary of Table 2 and the data flows are defined in Table 3. Note that in this case, the system is defined to include only the hardware and software materiel items. Consequently, the operator is considered to be outside the system. This is not necessarily the rule and often a system will be defined to include the human elements.

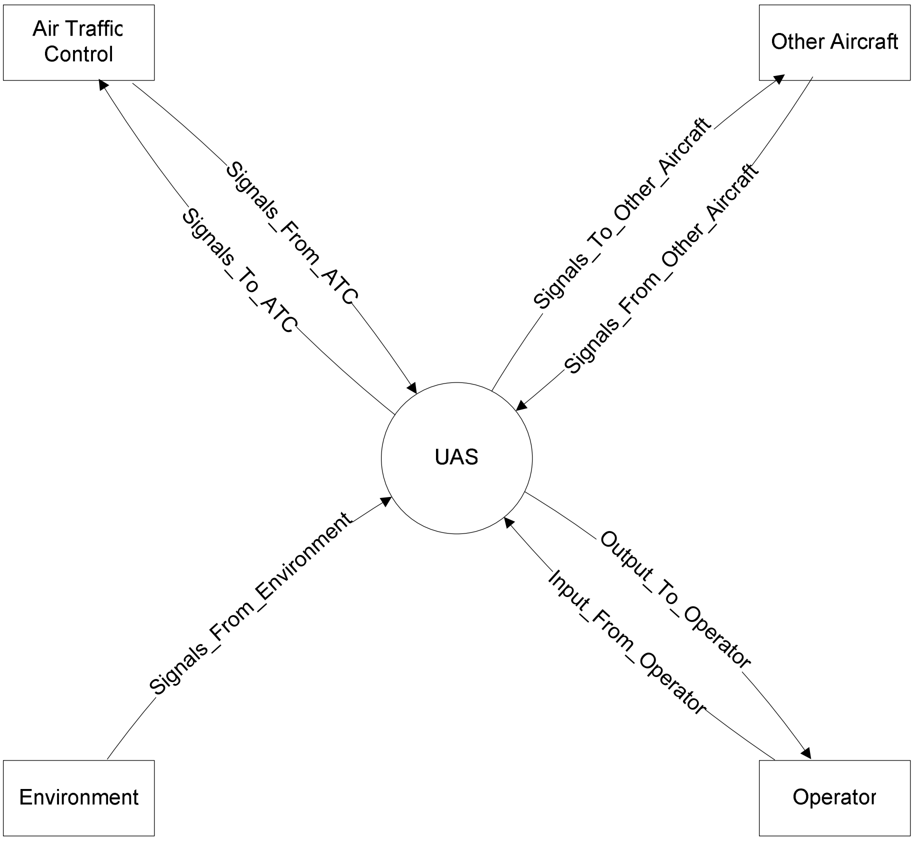

Figure 5 Context Diagram for the UAS

4.5 Checking of Requirements Analysis

Checks were performed on the analysis of the requirements in Table 1. The purpose of these checks was to ensure that the analysis was consistent. The following checks were made:

- That every row has a unique identifier in column (a);
- That every requirement is traceable to a paragraph in AC101-1(0) through an entry in column (b);
- That every row is marked as either a requirement or a non-requirement ('TRUE' or 'FALSE' respectively in column (d));

- That every requirement (column (d) = ‘TRUE’) has an appropriate requirement type in column (e); and

- That all non-requirements (column (d) = ‘FALSE’) have an entry of ‘N/A’ in column (e).

4.6 Results of the System Requirements Analysis

The requirements analysis performed at the system level, as described above, produced:

- Airworthiness regulations text formatted for analysis;

- Identification of the subset of regulations text which contains requirements;

- Classification of each requirement according to type;

- The system context diagram and data dictionary; and

- Checks on the analysis products.

CHAPTER 5 SYSTEM LEVEL FUNCTIONAL ANALYSIS

This chapter describes the functional analysis performed at the system level. The two purposes of this analysis were, firstly, to identify the implicit functionality required in the system, and secondly, to allocate functionality to subsystems.

5.1 The Functional Analysis Process

The method used for functional analysis in this work consists of the following steps:

(a) Create a function for each explicit system level functional requirement;

(b) Construct a hierarchy of functions;

(c) Construct functional flow diagrams;

(d) Iterate around steps (b) and (c), creating functions as needed to produce a consistent and logical function hierarchy and functional flow diagrams;

(e) Create a data dictionary to document the functions;

(f) Perform conceptual design at the system level to identify subsystems; and

(g) Allocate functions to subsystems.

These steps will be described in the following subsections.

5.2 Explicit System Functionality

A set of functions was created to implement the explicit system functional requirements. One function for each functional requirement in Table 1 was created. This set of functions was rationalised by combining similar functions. Traceability from each function back to its requirement was maintained. Aggregate functions traced to multiple requirements.

5.3 The Function Hierarchy

A hierarchy of functions was created by grouping similar functions.

High, middle and low level functions were created to complete the structure of the hierarchy. The creation of these functions was necessary because Table 1 contains requirements at the system, subsystem and component levels. For example, requirement C283 in Table 1 is a system level requirement that the operator should have the capability to turn the AV transponder on and off. This requires functionality to read the operator's command (function F1.2.10), functionality to control the power to the transponder (function F3.2.8) and functionality to communicate the command from the operator's position to the transponder's position (function F2). The functions which have been created are implicit in the system requirements and have been derived from the explicit requirements. The hierarchy of functions down to level 2 is shown in Figure 6.

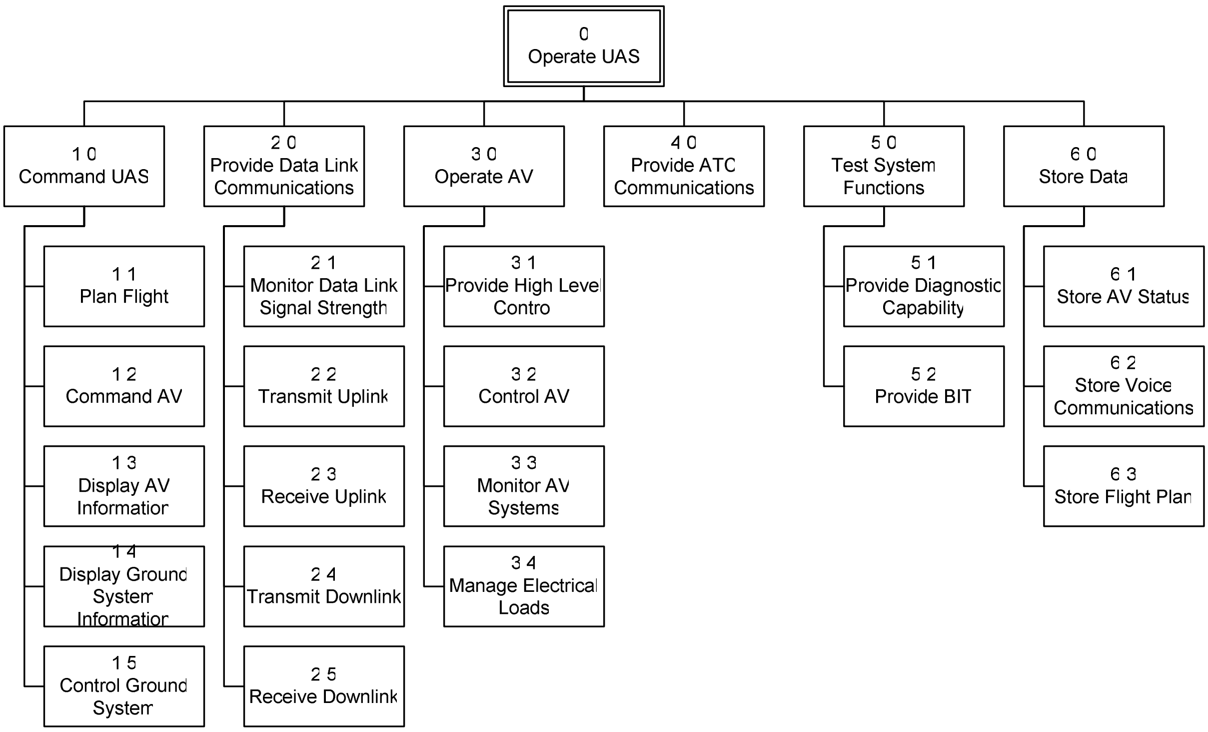

Figure 6 Function Hierarchy to Level 2

The function hierarchy shows how the high level functions of the system are composed of lower level functions. The full function hierarchy diagrams are contained in Appendix 4 (CHAPTER 13).

The hierarchy of functions is also contained in Table 4. Column (a) contains a unique identifier for each function. The identifier reflects the position of the function in the hierarchy and is prefixed with 'F' (for function). Columns (b), (c) and (d) contain the functions at levels one, two and three respectively in the hierarchy. Column (f) contains the identifier of the requirement(s) which specify the functionality. Column (g) contains the number of the AC101-1(0) paragraph which contains the requirement. Aggregate functions have multiple entries in columns (f) and (g). Derived functions have no entries in those columns.

5.4 Functional Flow Diagrams

Functional flow diagrams were used to assist in the decomposition of functionality and the construction of the function hierarchy. These diagrams are contained in Appendix 5 (CHAPTER 14).

Functional flow diagrams show the sequence of functions during operation of the system. The diagrams are based on the method described in Appendix A.1 of Blanchard and Fabrycky (1998). The purpose and notation of these functional flow diagrams are similar to IDEF0 diagrams. The functional flow diagram notation was used in preference to IDEF0 because it serves the same purpose and is more efficient to use with standard office drawing tools.

The functional flow for function F3.0 (Operate AV) is shown in Figure 7 below, to illustrate the notation.

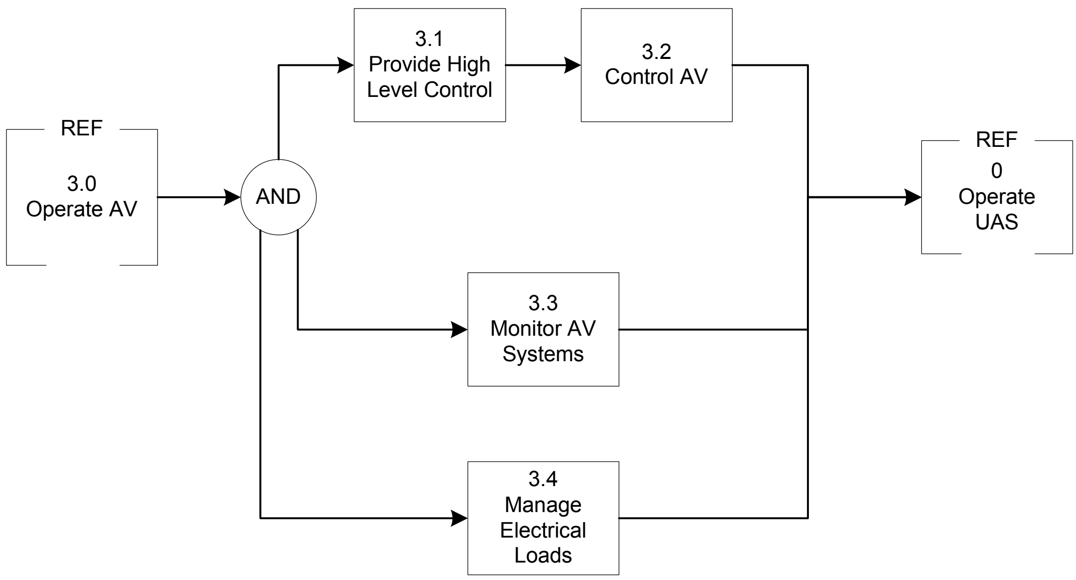

Figure 7.Functional Flow for Function F3.0 "Operate AV"

The reference block on the left side of Figure 7 with the arrow flowing out indicates a connection from another functional flow diagram. The reference block on the right side with the arrow flowing into it indicates a connection to another diagram. Functions 3.1 and 3.2 are executed sequentially. Functions 3.3 and 3.4 are executed in parallel with functions 3.1 and 3.2, as indicated by the AND symbol.

5.5 Initial System Design and the Product Breakdown Structure

The initial design activity at the system level is to decompose the system into subsystems. The result of this activity is the Product Breakdown Structure (PBS).

A PBS shows a hierarchical breakdown of a system into subsystems and components. Various references such as Cameron (1995) and Fahlstrom and Gleason (1992), provide overviews of UAS. Any of these system descriptions could be used as the basis for a top-level PBS. Another reference which provides a breakdown of a UAS is MIL-HDBK-881A (*Work Breakdown Structures for Defense Materiel Items* 2005). This could also form the basis of a UAS PBS. However the top-level PBS used here was developed from CASA (2002 paragraph 4.2). In this reference CASA define a UAS as consisting of the UAV, the ground control system, the communications/data link system, the maintenance system and the operating personnel (refer ID C14 of Table 1). The PBS developed from this definition is shown at Figure 8. For the purposes of this research, the personnel are not considered as part of the system.

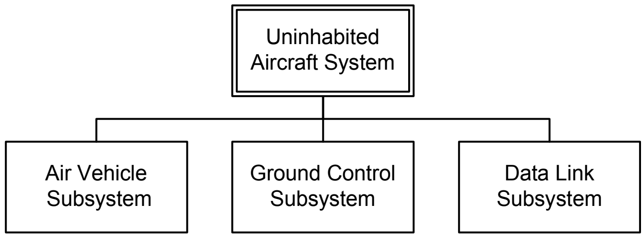

Figure 8 Product Breakdown Structure (to Level 2)

The elements of Figure 8 are defined in Table 2.

These are the top-level elements of a generic UAS. Many different UAS have elements which perform the same function. For example all UAS include an air vehicle as an element of the system. Different systems may use elements of the same type, such as a common hardware or software item. In general, most of the basic elements of a UAS will be found in all UAS. Hence, a top-level PBS which contains all of these basic elements may be defined and will be applicable to many specific UAS.

The UAS PBS is the top level system design and will provide a context for the consideration of requirements and functionality. Creating an arbitrary system design at the beginning may be seen as circumventing the systems engineering process, since the development of the system structure or architecture is one of the main products of that process. However, it is rare to apply a “pure text book” systems engineering process. In reality, many developments involve concurrent top-down and bottom-up engineering to produce a solution.

The UAS PBS is necessary for the allocation of requirements and functionality to physical subsystems.

5.6 Function Allocation

The final step in the functional analysis at the system level for this research was to allocate functionality to subsystems defined in the PBS. The lowest level functions in each branch of the function hierarchy were allocated to one or more of the Air Vehicle Subsystem (AVS), Data Link Subsystem (DLS) and Ground Control Subsystem (GCS). These allocations are shown in column (e) of Table 4.

5.7 Results of the System Functional Analysis

The functional analysis performed at the system level produced:

- Explicit functionality derived from the system requirements;
- Implicit functionality;
- A hierarchy of functions;
- Functional flow diagrams showing the sequential or parallel nature of each function;
- A high level system Product Breakdown Structure; and
- An allocation of functionality to PBS subsystems.

CHAPTER 6 SUBSYSTEM LEVEL ANALYSIS

6.1 Subsystem Functional Requirements

Systems engineering is an iterative process which is applied to the system, subsystem and component levels in a system. Analysis at the system level was described in CHAPTER 4 and CHAPTER 5. The starting point for analysis at the subsystem level is the definition of subsystem requirements, derived from the system level analysis.

Column (d) of Table 5 contains the subsystem functional requirements derived from the system level functional analysis for the level 2 subsystems of Figure 8.

6.2 Subsystem Conceptual Design

Conceptual design of the level 2 subsystems was then developed. The design was based upon the required functionality (from the system level analysis) and knowledge of the elements of existing UAS. The subsystem design is expressed as level 3 elements in the PBS. This design is shown in Figure 9.

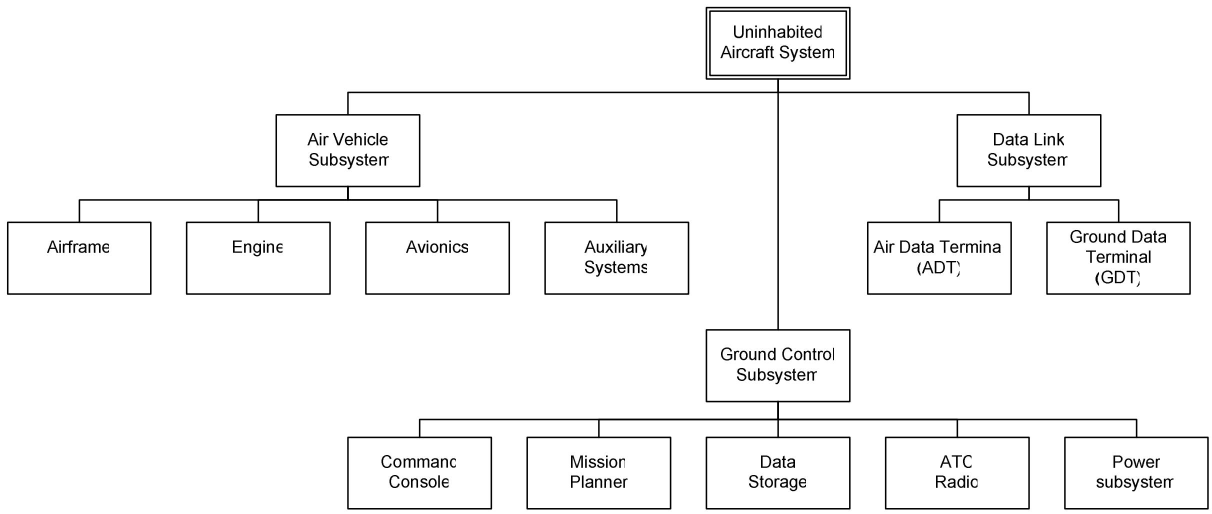

Figure 9 Product Breakdown Structure (to Level 3)

6.3 Functional Allocation to Subsystem Components

The subsystem requirements were allocated to components of the subsystems (i.e. the level 3 elements of the PBS). This allocation is contained in column (e) of Table 5.

CHAPTER 7 DISCUSSION

This chapter contains discussion of problems and observations made during the course of the research.

7.1 Tools

The research in this thesis employed standard office tools such as word processors, spreadsheets and office drawing packages (Microsoft Word, Excel and Visio). Although the result is adequate, the author considers that the result is disproportionate to the amount of effort required.

Any future effort should make use of tools specifically developed for managing requirements and performing requirements and functional analyses. These tools should provide a level of automation and specifically, a level of automated checking for consistency between the different engineering products.

7.2 Methodological problems

It was necessary to limit the scope of the topic to ensure that the research would be achievable in the available time. The scope was limited in a number of ways. These limitations contributed to many of the problems observed during the course of the research. The limitations are evident when the research is reviewed in the context of the full scope of systems engineering activities.

The scope of the research was limited by considering only a single airworthiness regulations document. A complete systems engineering analysis of airworthiness requirements would necessarily consider the complete range of documents.

Only one forward pass from requirements to functions was performed at the system level. At the subsystem level, only a requirements allocation was performed. A more complete analysis would involve iterative consideration of requirements and functionality at each of the system, subsystem and component levels.

During the requirements analysis activity, only the functional requirements were considered in detail. A full systems engineering analysis requires consideration and analysis of all requirements.

Additional activities such as safety and reliability analyses were not performed. These activities would normally generate additional requirements, including functional requirements. These additional requirements would be inputs to a subsequent iteration of the requirements analysis activity. Since these analyses were not performed, the additional requirements they would generate are not included in the analysis. Consequently the functional definition of the system is known to be incomplete.

Qualification criteria were not developed for the requirements. The development of qualification criteria is normally performed during requirements analysis. However, qualification criteria add little value to a functional architecture of a generic UAS. This is apparent when the reader recalls that the requirements and functional analyses are known to be incomplete. Formal architecture frameworks such the US Department of Defense Architecture Framework (DoDAF) do not contain qualification criteria.

The analysis of requirements and functionality was only performed on airworthiness requirements. No specific operational requirements were considered. Consequently, the resulting functional description is generic. While this has the advantage of being applicable to many systems, more work would be required to apply it to a specific system.

CHAPTER 8 CONCLUSION

8.1 Summary

This thesis has presented a functional description for a generic UAS. The functional description was derived from Australian civil airworthiness requirements (CASA 2002) through analysis of requirements and functionality.

The functional description identified the major functions in the system and the sequence of execution of functions during system operation.

8.2 Conclusions

This research has demonstrated that systems engineering provides a means of ensuring that the delivered system meets the customer's needs. This is illustrated in this thesis by the traceability from functionality back to requirements and from the subsystems up to the system level. The airworthiness regulations provide the customer's requirements in this research.

The decomposition of functionality has demonstrated that a UAS may be partitioned into subsystems with defined interfaces. This partitioning would allow the system to be developed by a distributed team.

Implementing the requirements analysis and functional analysis methods manually was time consuming. Automated tools would be needed for problems of any significant size or complexity.

A simulation model could be developed based upon the structure of the functional architecture.

8.3 Follow-On Work

The generic PBS does not limit the structure or implementation of an actual system. Depending on the operational requirements for a specific system, the following modifications may be needed to the generic functional description:

- A separate GCS may be required for each of launch and recovery if these are in different locations;
- Separate GCSs may be required for the launch/recovery and mission phases if the distance between the operational mission area and the launch/recovery area exceeds the range of data link communications;
- Command of the UAV may need to be transferred between multiple GCSs where the mission area is larger than the range of data link communications;
- A secondary command and control (C2) data link for redundant command and control of the UAV providing additional safety and reliability;
- The addition of payload functionality;
- A separate data link for payload data where this is needed in real-time or where the amount of data cannot be accommodated by the C2 data link(s);
- Integrated command and control of flight and payload where there are limitations on the number of human operators;
- Missions may comprise more than one sortie;
- Data link communications may be relayed between the GCS and UAV by a second UAV;
- UAVs may carry multiple payloads; and

- Swarming and cooperative flight.

The generic functional description will provide the basis for the development of more advanced architectures which include these options.

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CHAPTER 10 APPENDIX 1: REQUIREMENTS ANALYSIS OF AC101-1(0)

Table 1 contains the results of the analysis of the system requirements taken from an extract of AC101-1(0) (CASA 2002). The extract includes sections one through eight. Sections nine through 14 and the appendices were not included because they cover non-functional (certification, approval and insurance) and support (maintenance and training) aspects of a UAS.

Column (a) contains a unique identifier (pre-fixed with 'C' for CASA requirement) for each heading, sentence and list member of AC101-1(0).

Column (b) contains the paragraph number from Ac101-1(0).

Column (c) contains the heading, sentence or list member text from Ac101-1(0).

Column (d) indicates whether the text in column (c) is a requirement (TRUE) or not (FALSE).

Column (e) contains the requirement type(s) where column (c) contains a requirement or 'N/A' where the text is not a requirement. The requirement types are defined in Section 4.3.

Table 1 Requirements Analysis of Extract of AC101-1(0)

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C1	1	**1. REFERENCES**	FALSE	N/A
C2		· CASR Part 101	FALSE	N/A
C3	2	**2. PURPOSE**	FALSE	N/A
C4	2.1	2.1 This Advisory Circular (AC) has been developed to provide guidance to controllers and manufacturers of UAVs in the operation and construction of UAVs and the means whereby they may safely and legally operate UAV systems.	FALSE	N/A
C5	2.1	This document also provides guidance to CASA staff on the processing of approvals for UAV operation.	FALSE	N/A

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C6	2.1	While this document prescribes a means of compliance with legislation, alternate procedures demonstrating an equivalent or greater level of safety may be considered on a case by case basis.	FALSE	N/A
C7	3	**3. STATUS OF THIS AC**	FALSE	N/A
C8	3.1	3.1 This is the first AC to be published on this subject.	FALSE	N/A
C9	4	**4. BACKGROUND**	FALSE	N/A
C10	4.1	4.1 Flight by unmanned aerial vehicles (UAVs) in controlled airspace and over populous areas presents problems to the regulator in terms of ensuring the safety of other users of airspace and persons on the ground.	FALSE	N/A
C11	4.1	In the past, safety assurance would normally have been in the form of a prohibition of such activities, however, improvements in the technology associated with UAVs means that the potential exists for the operators of UAVs to comply with any safety imposition imposed by the regulator, which will ensure an adequate level of safety.	FALSE	N/A
C12	4.1	The penalties for the operator may be increased complexity, increased weight, reduced payload and increased cost.	FALSE	N/A
C13	4.1	In most cases, these factors will render commercial operations non-viable, however, as costs reduce and miniaturization continues, builders of UAVs may soon be able to develop cost effective solutions to current constraints.	FALSE	N/A
C14	4.2	4.2 The UAV comprises not just the aircraft, it also consists of the UAV ground control system, communications/datalink system, the maintenance system and the operating personnel.	FALSE	N/A
C15	4.2	Thus, when considering requests for UAV operating approval, the regulator will assess the UAV system as a whole.	FALSE	N/A
C16	4.2	The guidance contained in this advisory circular should be considered during development of a UAV system.	FALSE	N/A
C17	5	**5. OPERATION OF UAVS IN CONTROLLED AIRSPACE**	FALSE	N/A
C18	5.1	**5.1 General**	FALSE	N/A
C19	5.1.1	5.1.1 In general, when operating in controlled airspace, UAVs should be operated in accordance with the rules governing the flights of manned aircraft as specified by the appropriate ATS authority.	TRUE	Operational

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C20	5.1.1	UAVs should be able to comply with ATC regulations and equipment requirements applicable to the class of airspace within which they intend to operate.	TRUE	Design Constraint
C21	5.2	**5.2 Procedures and Authorisations**	FALSE	N/A
C22	5.2.1	5.2.1 The procedures and authorisations in this Section apply specifically to UAV operations within controlled airspace and include procedures and authorisations required to govern UAV take off, climb, descent, and landing.	FALSE	N/A
C23	5.2.1	These are required to provide for the pre co-ordination and procedures necessary to safely recover a UAV through controlled airspace should UAV system failure preclude the ability to remain outside controlled airspace.	FALSE	N/A
C24	5.2.2	5.2.2 These procedures apply specifically to those UAVs that can be monitored and controlled in real-time from a UAV control station.	FALSE	N/A
C25	5.2.2	Nothing contained in this document is meant to preclude operation of a UAV in an “autonomous” or programmed flight mode, provided that UAV performance and designated ATC communication circuits are continuously monitored by the UAV operating crew, and that the UAV system and crew are capable of immediately taking active control of the UAV.	FALSE	N/A
C26	5.3	**5.3 Flight Manual**	FALSE	N/A
C27	5.3.1	5.3.1 UAV flights in controlled airspace should only be conducted if an approved UAV Flight Manual is immediately available to the UAV controller within the UAV control station.	TRUE	Operational
C28	5.3.2	5.3.2 CASA may approve flights in controlled airspace by non-certificated UAVs.	FALSE	N/A
C29	5.3.2	In this case, CASA may require availability to the controller of reference material appropriate to the UAV being operated.	FALSE	N/A
C30	5.4	**5.4 Flight Testing**	FALSE	N/A
C31	5.4.1	5.4.1 UAV flight testing and certification flights should normally be conducted outside controlled airspace, however, flights within line of sight of the controller may be carried out in an approved operating area in accordance with an approval issued by CASA subject to ATC clearance.	TRUE	Operational
C32	5.5	**5.5 Rules of Operations**	FALSE	N/A

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C33	5.5.1	5.5.1 All flights outside visual sight of the controller should be conducted:	TRUE	Operational
C34	5.5.1a	(a) in accordance with conditions specified in an approval issued by CASA;	TRUE	Operational
C35	5.5.1b	(b) in an approved operating area; or	TRUE	Operational
C36	5.5.1c	(c) in a known traffic environment — in accordance with regulations governing the flight of a manned aircraft.	TRUE	Operational
C37	5.6	**5.6 Flight Notification**	FALSE	N/A
C38	5.6.1	5.6.1 Where a UAV flight is to be conducted in airspace shared with manned aircraft, flight notification may be in the form of a NOTAM or may be filed in accordance with the normal procedures for IFR flight.	TRUE	Operational
C39	5.6.1	The flight plan should indicate that the aircraft is unmanned and provide as much detail as possible concerning the nature of the flight.	TRUE	Operational
C40	5.6.2	5.6.2 The UAV may not enter controlled airspace without approval of the controlling authority; this would normally be in the form of an airways clearance. UAV flight procedures when operating within controlled airspace are as directed by the controlling authority.	TRUE	Operational
C41	5.6.3	5.6.3 When the operation of a UAV does not involve flight higher than 400 ft AGL or within close proximity to an aerodrome, the operator may exercise discretion in lodging flight notification.	TRUE	Operational
C42	5.6.3	Where there is doubt, the operator should seek guidance from CASA.	TRUE	Operational
C43	5.7	**5.7 Collision Avoidance**	FALSE	N/A
C44	5.7.1	5.7.1 Unless the controller of a UAV is provided with sufficient visual cues to enable the acquisition and avoidance of other air traffic, UAV flights in controlled airspace will be treated as IFR flights, subject to ATC control.	TRUE	Operational
C45	5.7.2	5.7.2 CASA may require a large UAV to be equipped with an SSR transponder, a collision avoidance system or forward looking television as appropriate for the type of operation.	TRUE	Design Constraint
C46	5.8	**5.8 Noise Abatement**	FALSE	N/A
C47	5.8.1	5.8.1 UAVs should follow applicable local noise abatement procedures at their launch and recovery sites such as operating hours, directed flight paths/altitudes, etc., consistent with safe operation of the UAV.	TRUE	Operational
C48	5.9	**5.9 Take off and Landing**	FALSE	N/A

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C49	5.9.1	5.9.1 When a UAV is operated at an aerodrome normally used by manned aircraft, take off and landing should be in accordance with normal procedures and the UAV should follow ATC instructions unless otherwise authorized.	TRUE	Operational
C50	5.9.2	5.9.2 For UAVs, which are manually controlled for, take off by the launch controller, VFR procedures, local airfield pattern regulation, and VFR weather minimums for the class of airspace will apply.	TRUE	Operational
C51	5.9.2	After take off, the launch controller should manoeuvre the UAV as required to maintain visual contact.	TRUE	Operational
C52	5.9.2	During take off and evolution from direct to autonomous control, the UAV system must be monitored by the UAV supervising controller to verify UAV system status and compliance with navigational and flight path clearances.	TRUE	Operational
C53	5.9.2	The supervising controller is responsible during this phase for collision avoidance but should allow the launch controller to manoeuvre the UAV as directed by ATC under IFR procedures.	TRUE	Operational
C54	5.9.3	5.9.3 For UAVs, which are manually controlled for landing by the launch controller, VFR procedures, local airfields pattern regulations, and VFR weather minimums for the class of airspace, will apply.	TRUE	Operational
C55	5.9.3	The UAV should be flown according to ATC instruction with traffic separation provided by ATC, to a pre-designated recovery point, entering a holding pattern until visual sight of the UAV is acquired by the supervising controller.	TRUE	Functional; Operational
C56	5.9.3	At this point, the supervising controller assumes responsibility for traffic separation and collision avoidance.	TRUE	Operational
C57	5.9.3	The supervising controller should monitor the recovery evolution to manual control to verify UAV performance and compliance with navigational and flight path clearances.	TRUE	Operational
C58	5.9.4	5.9.4 For UAVs equipped with automatic take off and landing systems, the supervising controller should monitor UAV system status and compliance with ATC clearances, making flight path corrections as required and/or directed by ATC.	TRUE	Operational
C59	5.1	**5.10 Emergency Procedures**	FALSE	N/A

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C60	5.10.1	5.10.1 The UAV flight plan should include information and procedures regarding pre-planned emergency flight profiles in the event positive data link control of the UAV is lost.	TRUE	Functional; Operational
C61	5.10.1	Dependent on system capabilities, these profiles could include:	FALSE	N/A
C62	5.10.1a	(a) UAV autonomous transit to a pre-designated recovery area followed by an autonomous recovery;	TRUE	Functional
C63	5.10.1b	(b) UAV autonomous transit to a pre-designated recovery area followed by activation of a flight termination system (FTS).	TRUE	Functional
C64	5.10.2	**5.10.2 Abort Procedures.**	FALSE	N/A
C65	5.10.2	Specific abort and flight termination procedures should be developed by the supervising UAV controller, and should be briefed to ATC as required.	TRUE	Operational
C66	5.10.2	At a minimum, information regarding pre-programmed loss-of-link flight profile (including termination actions should the control link not be re-established), flight termination capabilities, and UAV performance under termination conditions should be briefed.	TRUE	Operational
C67	5.10.3	5.10.3 The data link should be continuously and automatically checked and a real time warning should be displayed to the UAV crew in case of failure.	TRUE	Functional
C68	5.10.3	In case of loss of data link other than intermittent loss of signal or during programmed periods of outage, SSR 7700 code should be squawked both automatically and manually by the UAV controller and emergency recovery procedures should be executed.	TRUE	Functional; Operational
C69	5.10.3	The parameters, which determine acceptable intermittent loss of signal and total loss, will be set by the manufacturer.	TRUE	Performance
C70	5.10.3	A UAV, which has lost total control data link and is conducting an autonomous pre-programmed flight profile to termination or recovery will be handled by ATC as an emergency aircraft.	TRUE	Operational
C71	5.10.4	5.10.4 In the event of communications failure between the supervising UAV controller and ATC, the UAV should squawk SSR code 7600 (mode 3A) and attempt to establish alternate communications.	TRUE	Functional; Operational

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C72	5.10.4	Pending reestablishment of communications with ATC, the UAV will be controlled in accordance with last acknowledged instruction or should be commanded to orbit in its current position.	TRUE	Functional; Operational
C73	5.10.4	If communications with ATC are not re-established, the UAV sortie should be aborted.	TRUE	Operational
C74	5.11	**5.11 Meteorological Conditions**	FALSE	N/A
C75	5.11.1	5.11.1 Weather minimums for UAV flight should be determined by the equipment and capabilities of each specific UAV system, the qualifications of the supervising controller and the class of airspace in which the flight is conducted.	TRUE	Operational
C76	5.11.2	**5.11.2 Icing Conditions.**	FALSE	N/A
C77	5.11.2	UAVs should not be flown in conditions where icing may form without proper anti-ice/de-icing equipment.	TRUE	Design Constraint; Operational
C78	5.11.3	**5.11.3 Visibility.**	FALSE	N/A
C79	5.11.3	For UAVs operating under VFR procedures for launch and recovery, visibility requirements are as defined for the type of airspace, but in no case less than 5 km and 1000 foot ceiling.	TRUE	Operational
C80	5.11.3	For UAV systems equipped with an internal automatic precision landing aid such as those based on the Global Positioning Systems (GPS), weather minimums should be sufficient for an external observer to visually verify the UAV flight path and alert the UAV controllers of unsatisfactory landing approach in sufficient time to execute a missed approach; as such, minimum visibility is dependent on UAV approach speed, size, and performance capabilities.	TRUE	Operational
C81	5.12	**5.12 Co-ordination/Authorisation with CASA**	FALSE	N/A
C82	5.12.1	5.12.1 Subject to review, CASA may approve UAV systems for operations within published guidelines.	FALSE	N/A
C83	5.12.1	The review will include but not be limited to UAV certification, controller qualification, flight planning, weather minima, installed equipment and maintenance procedures.	FALSE	N/A
C84	5.12.1	Operations outside published guidelines will require special approval on a case-by-case basis.	FALSE	N/A
C85	5.12.2	**5.12.2 Local Operations.**	FALSE	N/A

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C86	5.12.2	Prior to the commencement of UAV operations, UAV operating personnel should establish Local Operating Procedures for UAV operations with the appropriate ATS authority.	TRUE	Operational
C87	5.12.2	Specific procedures should be established for ground UAV operations, flight plan filing procedures, integration of UAVs into local traffic pattern, UAV take off and landing procedures, local airspace restrictions, noise abatement procedures, right-of-way rules, communications requirements, and UAV emergency procedures.	TRUE	Operational
C88	5.12.2	Designated “safe areas” will be established for emergency UAV holding and flight termination.	TRUE	Operational
C89	5.13	**5.13 Interfacing with Air Traffic Services**	FALSE	N/A
C90	5.13.1	5.13.1 UAVs operating within radar controlled airspace should be equipped with a SSR transponder capable of operating in modes 3 A and C.	TRUE	Design Constraint
C91	5.13.1	The supervising UAV controller should have the capability to change the SSR code and squawk identification when required.	TRUE	Functional
C92	5.13.2	5.13.2 Flight Deviations. All requests for flight deviations should be made by established procedures to the appropriate ATS authorities.	TRUE	Operational
C93	5.13.3	5.13.3 Communications. The supervising UAV controller should initiate and maintain two way communications with the appropriate ATC authorities for the duration of any flight.	TRUE	Operational
C94	5.13.4	**5.13.4 Position Reporting.**	FALSE	N/A
C95	5.13.4	UAVs operating in controlled airspace should be continuously monitored for adherence to the approved flight plan by the supervising UAV controller.	TRUE	Functional; Operational
C96	5.13.4	The supervising UAV controller should make all position and other required reports to the appropriate ATC unit.	TRUE	Operational
C97	5.13.4	Automatic Dependent Surveillance systems (ADS) may be suitable for this purpose.	FALSE	N/A
C98	5.13.5	**5.13.5 Tracking.**	FALSE	N/A
C99	5.13.5	Where radar coverage is provided, ATC will continuously monitor the flight path of the UAV.	FALSE	N/A
C100	5.13.5	Outside of radar coverage, CASA may require the fitment of additional equipment to facilitate tracking of the UAV and separation from other aircraft.	TRUE	Design Constraint

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C101	5.13.5	ADS or similar equipment may be suitable for this purpose.	FALSE	N/A
C102	5.13.6	**5.13.6 UAV Identification.**	FALSE	N/A
C103	5.13.6	Each UAV flight should have some means of informing ATC that the flight is unmanned.	TRUE	Operational
C104	5.13.6	Therefore, all UAV call signs should include the word 'UNMANNED'.	TRUE	Operational
C105	5.14	**5.14 Line-of-Sight Operations**	FALSE	N/A
C106	5.14.1	5.14.1 For purposes of UAV operations within controlled airspace, 'line-of sight' refers to visual versus radio data link line-of-sight.	TRUE	Operational
C107	5.14.1	Accordingly, the only applicability to operations as discussed in this document is to the take off and landing phase.	FALSE	N/A
C108	5.14.1a	(a) Mission Briefing.	FALSE	N/A
C109	5.14.1a	The following information should be included in any flight authorisation requests and flight plans when applicable.	TRUE	Operational
C110	5.14.1a	When UAV take off and landing is to be accomplished by a launch controller under visual conditions, the supervising UAV controller should ensure appropriate airport/ATC personnel are briefed on the specific evolution of control to be conducted and are aware of the specific UAV operating procedures required.	TRUE	Operational
C111	5.14.1a	In addition to the information required for the flight plan, procedures for UAV taxi, take off, separation, local traffic pattern restrictions, controller hand-over, departure, abort to recovery, and flight termination should be briefed.	TRUE	Operational
C112	5.14.1b	(b) Communication Requirements.	FALSE	N/A
C113	5.14.1b	Communication requirements for UAV line-of-sight operations are as required for the class of airspace in which the flight will occur.	TRUE	Design Constraint; Operational
C114	5.14.1b	When the flight controller is not co-located with the launch controller, the launch and recovery control station as well as the primary UAV control station must have established communications with ATC authorities responsible for the area of flight prior to commencement of flight.	TRUE	Functional; Operational
C115	5.15	**5.15 Operations Beyond Line-of-Sight**	FALSE	N/A
C116	5.15.1	5.15.1 Mission Briefing. The following information should be included in any flight authorization requests and flight plans when applicable.	TRUE	Operational
C117	5.15.2	**5.15.2 Performance Requirements.**	FALSE	N/A

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C118	5.15.2	Any performance requirements or limitations unique to the UAV should be provided to the ATC unit as appropriate prior to the flight.	TRUE	Operational
C119	5.15.2	The pilot in command should not request any clearance (i.e. SID, precision approach, altitude, holding pattern) that the UAV is not capable of executing within its approved flight envelope.	TRUE	Operational
C120	5.15.3	**5.15.3 Abort Procedures.**	FALSE	N/A
C121	5.15.3	Specific abort and flight termination procedures should be developed by the supervising UAV controller, and should be provided to ATC as required.	TRUE	Operational
C122	5.15.3	At a minimum, information regarding pre-programmed loss-of-link flight profile (including terminal actions should the control link not be re-established), flight termination capabilities, and UAV performance under termination conditions should be briefed.	TRUE	Operational
C123	5.15.4	**5.15.4 Direct Communications Required.**	FALSE	N/A
C124	5.15.4	Communications between the supervising UAV controller and the controlling ATC authority should be as required for the class of airspace in which operations occur.	TRUE	Design Constraint; Operational
C125	5.15.4	The UAV control station should utilize a communications architecture, which interfaces with existing ATC communications equipment and procedures, so that the fact that the supervising UAV controller is on the ground is transparent to ATC personnel.	TRUE	Design Constraint
C126	5.15.4	Upon check-in with ATC personnel, the supervising controller should request a direct telephone number for ATC for contingency use should radio communications fail.	TRUE	Operational
C127	5.15.5	**5.15.5 Chase Plane Requirements.**	FALSE	N/A
C128	5.15.5	Chase planes are not required for UAVs operating in controlled airspace when on approved IFR flight plans and in accordance with the procedures outlined in this AC.	TRUE	Operational
C129	5.15.5	During flights or portions of flights under IFR procedures if a chase plane is utilized, the chase plane must be incorporated into the IFR flight plan.	TRUE	Operational
C130	5.15.5	In such a case, the flight will be classified as a formation flight, and will have the same right-of-way status as aircraft engaged in towing.	TRUE	Operational

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C131	5.15.5	A chase plane should not be utilized in conjunction with UAV IFR flight operations when VFR conditions applicable for the class of airspace cannot be maintained.	TRUE	Operational
C132	5.15.6	5.15.6 Qualification of the Supervising UAV Controller. At a minimum, the supervising UAV controller should have completed the ground training applicable to the issue of an instrument rating in order to operate UAVs in controlled airspace under an IFR clearance.	TRUE	Operational
C133	5.16	**5.16 Operation of Equipment**	FALSE	N/A
C134	5.16.1	5.16.1 Equipment Requirements. The following equipment should be fitted and operable prior to a flight under IFR procedures:	TRUE	Operational
C135	5.16.1a	(a) Position Lights. These lights should normally be turned on at all times the UAV is in motion including taxi, takeoff, flight, and landing, unless otherwise approved by CASA.	TRUE	Design Constraint
C136	5.16.1b	(b) Anti-Collision Lights. These lights should normally be turned on at all times the UAV is in flight unless otherwise directed by CASA.	TRUE	Design Constraint
C137	5.16.1c	(c) Transponder. The supervising controller should have the capability to turn the transponder on and off, manually select codes, and squawk and identification as directed, while the UAV is airborne.	TRUE	Functional
C138	5.16.1d	(d) Radios. UAV communication architecture should allow the supervising UAV controller to communicate with the ATC facilities controlling the UAV regardless of its location.	TRUE	Design Constraint
C139	5.16.1e	(e) Acquisition light. The light should be operable on command as an aid to identification of the UAV.	TRUE	Design Constraint
C140	5.16.2	5.16.2 UAV System and Attitude Displays. The UAV system should be capable of displaying to the supervising controller all aircraft system and attitude information necessary for safe operation, control, and navigation.	TRUE	Functional; Safety
C141	5.16.3	**5.16.3 Flight and Voice Recorder.**	FALSE	N/A
C142	5.16.3	Where recording systems are required by CASA to record UAV systems and navigational status, and radio and intercom voice communications, such systems should be operable for the duration of the flight.	TRUE	Performance
C143	5.16.3	This system will normally be installed within the UAV control station.	FALSE	N/A

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C144	5.16.4	5.16.4 Flight Termination. UAVs should not operate within controlled airspace without an operable flight termination system or a system which provides autonomous recovery to a predetermined recovery area following failure to maintain safe flight control or operation within parameters agreed by the operators and CASA.	TRUE	Design Constraint; Operational
C145	6	**6. OPERATION OF UAVS OVER POPULOUS AREAS**	FALSE	N/A
C146	6.1	**6.1 General**	FALSE	N/A
C147	6.1.1	6.1.1 The paramount factor to be addressed when considering flight by UAVs over populous areas is the safety of people and property on the ground.	FALSE	N/A
C148	6.1.1	The risk of injury or damage resulting from the crash of a UAV is dependent upon a variety of factors:	FALSE	N/A
C149	6.1.1a	(a) mass of the UAV;	FALSE	N/A
C150	6.1.1b	(b) composition of the UAV;	FALSE	N/A
C151	6.1.1c	(c) velocity of the UAV at impact.	FALSE	N/A
C152	6.1.2	6.1.2 The potential of the UAV to crash is also dependent upon a variety of factors:	FALSE	N/A
C153	6.1.2a	(a) integrity of the airframe;	FALSE	N/A
C154	6.1.2b	(b) reliability of the engine;	FALSE	N/A
C155	6.1.2c	(c) reliability of control systems;	FALSE	N/A
C156	6.1.2d	(d) reliability of the control communications system;	FALSE	N/A
C157	6.1.2e	(e) ability of the controller.	FALSE	N/A
C158	6.1.3	6.1.3 CASA is charged with the responsibility of ensuring the safety of flying operations, the following guidance in this section has been developed for that purpose.	FALSE	N/A
C159	6.2	**6.2 Procedures and Authorisation**	FALSE	N/A
C160	6.2.1	6.2.1 The procedures and authorisations in this Section apply specifically to UAV operations over populous areas and are additional to any requirements specified in Section 5 where populous areas and controlled airspace are coincident.	FALSE	N/A
C161	6.2.2	6.2.2 These procedures apply specifically to those UAVs that can be monitored and controlled in real-time from a UAV control station or which are operated by line of sight control.	FALSE	N/A
C162	6.2.2	Nothing herein is meant to preclude operation of a UAV in an 'autonomous' or programmed flight mode, provided that UAV navigation performance can be continuously monitored by the UAV controllers, and that the UAV system and crew are capable of immediately taking active control of the UAV.	FALSE	N/A

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C163	6.3	**6.3 Flight Manual**	FALSE	N/A
C164	6.3.1	6.3.1 UAV flights over populous areas should be conducted only if an approved UAV Flight Manual is immediately available to the supervising UAV controller within the UAV control station. (See paragraph 5.3).	TRUE	Operational
C165	6.4	**6.4 Flight Testing**	FALSE	N/A
C166	6.4.1	6.4.1 UAV flight testing and certification may not be carried out over populous areas.	TRUE	Operational
C167	6.5	**6.5 Rules of Operations**	FALSE	N/A
C168	6.5.1	6.5.1 UAV flights over populous areas may not be conducted except:	TRUE	Operational
C169	6.5.1a	(a) by a UAV certificated for such flight; and	TRUE	Operational
C170	6.5.1b	(b) in accordance with conditions specified in an approval issued by CASA; or	TRUE	Operational
C171	6.5.1c	(c) at an altitude which would allow the UAV to clear the area in the event of engine failure.	TRUE	Operational
C172	6.5.2	6.5.2 Generally, the requirement for certification will limit flights over populous areas to large UAVs, however, the designer of a small UAV may apply for a type certificate subject to the requirements of CAR 1998 Part 21 and accompanying advisory material. Provided that the aircraft meets CASA's requirements, the UAV may be eligible for certification.	FALSE	N/A
C173	6.6	**6.6 Noise Abatement**	FALSE	N/A
C174	6.6.1	6.6.1 UAVs should follow the principles of noise abatement procedures during flight over populous areas consistent with safe operation of the UAV.	TRUE	Operational
C175	6.7	**6.7 Emergency Procedures**	FALSE	N/A
C176	6.7.1	6.7.1 The UAV flight plan should include procedures to be followed in the event of:	TRUE	Operational
C177	6.7.1a	(a) engine failure;	TRUE	Functional; Operational
C178	6.7.1b	(b) loss of data link;	TRUE	Functional; Operational
C179	6.7.1c	(c) loss of control;	TRUE	Functional; Operational
C180	6.7.1d	(d) failure of navigation;	TRUE	Functional; Operational
C181	6.7.1e	(e) airframe damage.	TRUE	Functional; Operational

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C182	6.7.2	6.7.2 Emergency procedures may include the use of recovery devices, such as parachutes, where a failure subjects persons or property to immediate danger or, where the immediate risk of hazard from failure is minimal:	TRUE	Operational
C183	6.7.2a	(a) UAV autonomous transit to a pre-designated recovery area followed by an autonomous recovery;	TRUE	Functional
C184	6.7.2b	(b) UAV autonomous transit to a pre-designated recovery area followed by activation of a flight termination system.	TRUE	Functional
C185	7	**7. UAV OPERATION OVER UNPOPULATED AREAS**	FALSE	N/A
C186	7.1	**7.1 Small UAVs**	FALSE	N/A
C187	7.1.1	7.1.1 Provided that a small UAV is operated not above 400ft AGL and remains clear of designated airspace, aerodromes and populous areas, there are no restrictions imposed upon the operation of a small UAV.	TRUE	Operational
C188	7.1.1	The operator is responsible for ensuring that the UAV is operated safely and remains clear of potential low level traffic, structures, powerlines etc, except where operation in close proximity is part of an operation authorised on the operator's operating certificate.	TRUE	Operational
C189	7.1.1	The operator should consider the benefit of a thorough reconnaissance of the proposed route beforehand.	TRUE	Operational
C190	7.1.2	7.1.2 Where a person wishes to operate a small UAV above 400ft AGL, that person must do so in accordance with conditions imposed by CASA. Such conditions may specify:	TRUE	Operational
C191	7.1.2a	(a) maximum altitudes;	TRUE	Operational
C192	7.1.2b	(b) communication requirements;	TRUE	Operational
C193	7.1.2c	(c) operating times;	TRUE	Operational
C194	7.1.2d	(d) operating area limitations;	TRUE	Operational
C195	7.1.2e	(e) UAV equipment etc.	TRUE	Operational
C196	7.2	**7.2 Large UAVs**	FALSE	N/A
C197	7.2.1	7.2.1 A person wishing to operate a large UAV may only do so if it has been issued with Certificate of Registration and either an Experimental certificate or a certificate of airworthiness in the Restricted category and is operated in accordance with an approval issued by CASA.	TRUE	Operational
C198	8	**8. DESIGN SPECIFICATION FOR UAV SYSTEMS**	FALSE	N/A

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C199	8.1	**8.1 General**	FALSE	N/A
C200	8.1.1	8.1.1 A UAV system comprises both airborne and ground based equipment and should be designed to minimize the potential for a failure of any component to prevent continued safe flight and recovery of the UAV.	TRUE	Design Constraint
C201	8.1.1	Because of the wide range of airborne vehicles and ground stations which potentially form part of a UAV system and the wide diversity of possible operations, some design criteria may apply to all UAV systems and some may be unique to a type or class of UAV.	FALSE	N/A
C202	8.1.1	Thus, the potential developer of a UAV system is encouraged to consult with CASA prior to commencement of a project.	FALSE	N/A
C203	8.1.1	The following design criteria are for general guidance only.	FALSE	N/A
C204	8.1.2	8.1.2 The guidance pertains to the design of seven critical UAV subsystems for operations outside of an approved operating area:	FALSE	N/A
C205	8.1.2a	(a) flight control;	FALSE	N/A
C206	8.1.2b	(b) electrical;	FALSE	N/A
C207	8.1.2c	(c) communications/data link;	FALSE	N/A
C208	8.1.2d	(d) navigation;	FALSE	N/A
C209	8.1.2e	(e) propulsion;	FALSE	N/A
C210	8.1.2f	(f) UAV control station;	FALSE	N/A
C211	8.1.2g	(g) flight termination.	FALSE	N/A
C212	8.2	**8.2 Design Criteria**	FALSE	N/A
C213	8.2.1	8.2.1 Flight control design should facilitate control of the UAV by the controller and provide unambiguous operations and clear indications of UAV flight status.	TRUE	Functional
C214	8.2.1	Design criteria should minimise the potential for human error.	TRUE	Design Constraint
C215	8.2.1	All flight indications and warnings necessary to ensure safe control of the UAV flight path should be provided.	TRUE	Safety
C216	8.2.1	In particular, the supervising controller should be informed of any degraded mode of operations due to any failure, including cases in which there is an automatic switching to an alternate or degraded mode of operation.	TRUE	Functional
C217	8.2.1	The control station should include a diagnostic and monitoring capability for the status of the vehicle.	TRUE	Functional
C218	8.2.1	Real time, direct communications/surveillance, and continuous data transmission capability should be provided.	TRUE	Functional

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C219	8.2.2	8.2.2 A UAV system should incorporate a fail-safe flight termination system (FTS) or autonomous recovery system (ARS), which provides recovery to a predetermined recovery area.	TRUE	Design Constraint
C220	8.2.2	This system should operate on demand or automatically following failure to maintain safe flight control or operation within parameters agreed by the operators and CASA.	TRUE	Functional
C221	8.2.2	The need for this feature will be given greater emphasis where operations are planned over or close to populous areas or where they will be within or close to controlled airspace.	FALSE	N/A
C222	8.2.2	Less emphasis on a FTS/ARS will be accorded for those UAVs operating in remote areas.	FALSE	N/A
C223	8.3	**8.3 Safety Standards**	FALSE	N/A
C224	8.3.1	8.3.1 UAV operations should be as safe as manned aircraft insofar as they should not present or create a hazard to persons or property in the air or on the ground greater than that created by manned aircraft of equivalent class or category.	TRUE	Safety
C225	8.4	**8.4 Registration**	FALSE	N/A
C226	8.4.1	8.4.1 CASA requires the operator of a large UAV to hold a certificate of registration for the aircraft and to maintain the information required for compilation of UAV reliability and failure rates.	TRUE	Operational
C227	8.4.2	8.4.2 Although a small UAV is exempt from the requirement for registration, each UAV should have affixed to it a durable identification plate inscribed with appropriate marks to identify ownership and identity of the particular aircraft.	TRUE	Design Constraint
C228	8.5	**8.5 Technical Issues and Related Criteria**	FALSE	N/A
C229	8.5.1	8.5.1 Proven fail-safe principles will govern the design of UAV systems.	TRUE	Design Constraint
C230	8.5.1	System independence and adequate redundancy and back-up features should provide for safe functioning of the UAV in the event of a system failure.	TRUE	Design Constraint
C231	8.5.1	Redundancy of system management functions also should be built into the system.	TRUE	Design Constraint
C232	8.5.1	A description of what constitutes 'fail-safe' design appears at Appendix 2.	TRUE	Design Constraint
C233	8.5.2	8.5.2 UAV system design should provide for a failure detection apparatus (pre-flight and in-flight built-in-test) that will immediately notify the supervising controller of a system failure.	TRUE	Functional

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C234	8.5.2	Adequate provision for the safe operation of the UAV following a system failure should be provided.	TRUE	Design Constraint
C235	8.5.2	Potential human UAV controller errors should be considered by UAV designers and adequate provisions should be taken to minimize the effects of such errors.	TRUE	Design Constraint
C236	8.5.2	Additionally, an engineering analysis of any UAV design should be submitted to CASA to assist in the further review of UAV design criteria.	TRUE	Certification
C237	8.5.2	The following are considered critical system design criteria for UAVs.	FALSE	N/A
C238	8.5.3	**8.5.3 Software.**	FALSE	N/A
C239	8.5.3	All UAV system software should be verified and validated in accordance with RTCA document DO-178B or equivalent.	TRUE	Design Constraint
C240	8.5.3	Safety critical software may be subject to additional verification by CASA.	TRUE	Design Constraint
C241	8.5.4	**8.5.4 Flight Management System.**	FALSE	N/A
C242	8.5.4	The flight management system includes UAV controller controls, sensors, computers and actuation parts necessary to control the UAV.	FALSE	N/A
C243	8.5.4	Any single failure of the flight control system should not affect the ability to control UAV recovery.	TRUE	Design Constraint
C244	8.5.4	Provisions for possible reversion to degraded modes of operation also should be incorporated into flight management system design.	TRUE	Design Constraint
C245	8.5.4	Provision for continued control of the UAV should be made in the event of a propulsion or power generation system failure.	TRUE	Design Constraint
C246	8.5.5	**8.5.5 Electrical System.**	FALSE	N/A
C247	8.5.5	The electrical system should provide sufficient power and endurance to ensure safe operations and recovery throughout all phases of flight even in the event of an emergency.	TRUE	Design Constraint
C248	8.5.5	Consideration should be given to the ability to shed non-essential load in the event of a power generation failure.	TRUE	Functional
C249	8.5.5	Similar considerations apply to the ground control station.	TRUE	Functional
C250	8.5.6	**8.5.6 Communications System/Data Link.**	FALSE	N/A
C251	8.5.6	Approval for all frequencies used in UAV operations must be obtained from national authorities.	TRUE	Design Constraint
C252	8.5.6	Data link signal strength should be continuously monitored and appropriate maximum data link range cues should be provided to the supervising controller.	TRUE	Functional

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C253	8.5.6	Any single failure of the communications system (uplink or downlink) should not affect normal control of the UAV.	TRUE	Design Constraint
C254	8.5.6	Uplinks/downlinks are sensitive to electromagnetic interference (EMI) and should be adequately protected from this hazard.	TRUE	Design Constraint
C255	8.5.6	Provisions for direct communications between the supervising controller and the appropriate ATC via two way radio should be incorporated in the system design.	TRUE	Design Constraint
C256	8.5.7	**8.5.7 Navigation System.**	FALSE	N/A
C257	8.5.7	The UAV navigation system should meet the required navigation performance standards of the flight rules and the specific requirements for the airspace in which the operations are to be conducted.	TRUE	Performance
C258	8.5.7	Only navigation systems meeting the requirements for 'sole means navigation' will normally be considered for flights under IFR and in controlled airspace.	TRUE	Design Constraint
C259	8.5.8	8.5.8 Propulsion System. All essential elements of the propulsion system should meet required reliability standards as approved by CASA.	TRUE	Design Constraint
C260	8.5.9	**8.5.9 UAV Control Station.**	FALSE	N/A
C261	8.5.9	In its simplest form, the UAV control station may consist of a hand held transmitter incorporating basic flight controls and rudimentary displays similar to those of a model aircraft.	FALSE	N/A
C262	8.5.9	Control stations for UAV operations beyond line of sight should include controls and displays for aircraft attitude and performance, propulsion, navigation, aircraft systems and sensor operation as well as flight system and voice recording equipment.	TRUE	Functional
C263	8.5.9	CASA will assess the control station against the requirement to assure the safety of air navigation of the UAV.	FALSE	N/A
C264	8.5.10	**8.5.10 UAV Structure.**	FALSE	N/A
C265	8.5.10	UAV aircraft structure should be designed to withstand the maximum expected operational loads as determined by the intended operational flight envelope of the UAV.	TRUE	Design Constraint
C266	8.5.10	Structural design of small UAVs should meet the standards applicable to the construction of model aircraft of the same weight category, which may be obtained from the Model Aircraft Association of Australia (MAAA).	TRUE	Design Constraint

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C267	8.5.10	Large UAVs should comply with the appropriate design requirements advised by letter in accordance with CAR 1998 Part 21.	TRUE	Design Constraint
C268	8.5.11	**8.5.11 Flight Termination System.**	FALSE	N/A
C269	8.5.11	A UAV system should incorporate a fail-safe flight termination system (FTS) or autonomous recovery system (ARS), which provides recovery to a predetermined recovery area.	TRUE	Design Constraint
C270	8.5.11	This system should operate on demand or automatically following failure to maintain safe flight control or operation within parameters agreed by the operators and CASA.	TRUE	Functional
C271	8.5.11	The need for this feature will be given greater emphasis where operations are planned over or close to populous areas or where they will be within or close to controlled airspace.	FALSE	N/A
C272	8.5.11	Less emphasis on a FTS/ARS will be accorded for those UAVs operating in remote areas.	FALSE	N/A
C273	8.6	**8.6 Equipment requirements**	FALSE	N/A
C274	8.6.1	8.6.1 The following equipment and instrument capabilities should be installed on the UAV and/or be available to the supervising controller in order to comply with the requirements for safe flight under IFR procedures:	TRUE	Operational
C275	8.6.1a	(a) Position Lights.	FALSE	N/A
C276	8.6.1a	UAVs should have position lights installed as required.	TRUE	Design Constraint
C277	8.6.1a	The UAV supervising controller may be given the capability to turn these lights on and off while the UAV is airborne, however they will normally be turned on at all times the UAV is in motion including taxi, takeoff, flight, and landing, unless otherwise directed by CASA.	TRUE	Functional
C278	8.6.1b	(b) Anti-Collision Lights.	FALSE	N/A
C279	8.6.1b	UAVs should have strobe lights installed as required.	TRUE	Design Constraint
C280	8.6.1b	The UAV supervising controller may be given the capability to turn these lights on and off while the UAV is airborne, however they will normally be turned on at all times the UAV is in flight unless otherwise directed by CASA.	TRUE	Functional
C281	8.6.1c	(c) Transponder.	FALSE	N/A
C282	8.6.1c	For operation in controlled airspace, and where otherwise required by CASA, UAVs should have an operable SSR transponder installed.	TRUE	Design Constraint

(a) Reqt ID	(b) AC101-1(0) Para	(c) Object Text	(d) Is A Reqt?	(e) Reqt Type
C283	8.6.1c	The supervising controller should have the capability to turn the transponder on and off, manually select codes, and squawk and identification as directed, while the UAV is airborne.	TRUE	Functional
C284	8.6.1c	CASA may approve operation without in-flight resettable SSR codes and identification capability on a case by-case basis.	FALSE	N/A
C285	8.6.1d	(d) Radios.	FALSE	N/A
C286	8.6.1d	The supervising controller should have full and immediate access to two way radios within the UAV control station as required to maintain communications.	TRUE	Design Constraint
C287	8.6.1d	UAV communication architecture will be designed to allow the supervising controller to communicate with the ATC facilities and UAV ground crews controlling the UAV regardless of their location.	TRUE	Design Constraint
C288	8.6.1e	(e) Navigation Systems.	FALSE	N/A
C289	8.6.1e	Navigational information should be available to the supervising controller in a format required for reporting in accordance with ATC requirements.	TRUE	Design Constraint
C290	8.6.1f	(f) UAV System and Attitude Displays.	FALSE	N/A
C291	8.6.1f	The UAV system should display to the supervising controller all aircraft system and attitude information required for safe operation, control, and navigation.	TRUE	Safety
C292	8.6.1g	(g) Flight and Voice Recorder.	FALSE	N/A
C293	8.6.1g	CASA may require the UAV system to have a recorder to record UAV systems and navigational status, and radio and intercom voice communications.	TRUE	Functional
C294	8.6.1g	This recorder will normally be installed within the UAV control station.	FALSE	N/A
C295	8.6.1h	(h) Built-in Test.	FALSE	N/A
C296	8.6.1h	Some aircraft may require procedures designed to exercise critical components and systems and provide an indication of their state of health together with an appropriate display.	TRUE	Functional
C297	8.6.1h	This information may be available to the ground station during flight.	TRUE	Performance
C298	8.6.1h	A set of diagnostic procedures should also be included to aid fault location.	TRUE	Operational
C299	8.6.1h	For in-flight use this should include remaining emergency power reserve.	TRUE	Functional

The following sections of AC101-1(0) are not included in Table 1:

- Section 9 Unmanned Aerial Vehicle Certification;
- Section 10 UAV System Maintenance;
- Section 11 Training Requirements for Pilots and Controllers of UAVs;
- Section 12 Getting Approval;
- Section 13 Operator Certification;
- Section 14 Insurance; and
- Appendices 1, 2 and 3.

CHAPTER 11 APPENDIX 2: DATA DICTIONARY

11.1 Physical Objects

Table 2 contains the definitions of names of physical objects from the context diagram and the Product Breakdown Structure.

Table 2 Dictionary of Physical Objects

Object	Description
Air Data Terminal (ADT)	The component of the DLS which is integrated into the AVS and communicates with the GDT.
Air Traffic Control (ATC)	The external system which coordinates and directs air traffic movement.
Air Vehicle Subsystem (AVS)	The Air Vehicle excluding the data link and payload.
Airframe	The structure of the AVS.
ATC Radio	The radio which provides the means of communication between the operator and ATC.
Auxiliary Systems	AVS subsystems such as electrical power generation and distribution, hydraulics and pneumatics but excluding avionics and propulsion.
Avionics	The electronics and computing components of the AVS which provide control and monitoring functionality.
Command Console	The component of the GCS which provides the interface to the operator.
Data Link Subsystem (DLS)	The subsystem which provides data communications between the GCS and AVS.
Data Storage	The component of the GCS which provides storage of data and voice communication recordings.
Engine	The propulsion system of the AVS.
Environment	Everything external to the UAS with the exception of ATC, other aircraft and the operator.
Ground Control Subsystem (GCS)	The ground based subsystems necessary for the launch, operation and recovery of an Uninhabited Air Vehicle.
Ground Data Terminal (GDT)	The component of the DLS which interfaces to the GCS and communicates with the ADT.
Mission Planner	The component of the GCS which provides the capability for teh operator to plan flights.
Operator	The human operator of the UAS.
Other Aircraft	Aircraft other than the Air Vehicle of the UAS.
Power Subsystem	
Uninhabited Aircraft System (UAS)	The subsystems, both airborne and ground based, necessary for the operation of an Uninhabited Air Vehicle.

11.2 Data flows

Table 3 defines the data flows from the Context Diagram of Figure 5.

Table 3 Dictionary of Data Flows

Data Flow Name	From	To	Description
Input_From_Operator	Operator	UAS	Consists of manual inputs and voice communications from the operator.
Output_To_Operator	UAS	Operator	Consists of output from the console display and voice communications to the operator.
Signals_From_ATC	ATC	UAS	Consists of voice communications from ATC and radar signals
Signals_From_Environment	Environment	UAS	Consists of the signals sensed from the environment, possibly including static and total pressures, angles of attack and sideslip, magnetic heading and satellite navigation signals.
Signals_From_Other_Aircraft	Other Aircraft	UAS	Consists of signals emitted or reflected by another aircraft.
Signals_To_ATC	UAS	ATC	Consists of voice communications from the operator and transponder squawks in response to ATC radar signals
Signals_To_Other_Aircraft	UAS	Other Aircraft	These signals may include emissions from an active collision avoidance system.

CHAPTER 12 APPENDIX 3: FUNCTIONAL ANALYSIS OF AC101-1(0)

Table 4 contains the results of functional analysis of the functional requirements from Table 1.

Column (a) contains a unique identifier (pre-fixed with 'F' for function) for each function. The identifier reflects the structure of the hierarchy of functions.

Column (b) contains the functions at level one in the hierarchy.

Column (c) contains the functions at level two in the hierarchy.

Column (d) contains the functions at level three in the hierarchy.

Column (e) contains the subsystem or subsystems which the function is allocated to. The subsystems are from the level 2 PBS in Figure 8 and are the Ground Control Subsystem (GCS), the Data Link Subsystem (DLS) and the Air Vehicle Subsystem (AVS).

Column (f) contains the identifier(s) of the requirement(s) in Table 1 which specify the need for the function.

Column (g) contains the number of the AC101-1(0) paragraph which contains the requirement.

Where columns (f) and (g) are empty, this indicates that the function does not trace directly to a requirement, but was derived during either the requirements analysis or functional analysis process.

Table 4 Functionality from AC101-1(0)

(a) ID	(b) Functions - level 1	(c) Functions - level 2	(d) Functions - level 3	(e) Allocated To	(f) Reqt ID	(g) Reqt Para
F1	Command UAS					
F1.1		Plan flight				
F1.1.1			Plan engine failure procedure	GCS	C177	6.7.1a
F1.1.2			Plan lost data link procedure	GCS	C60 C178	5.10.1 6.7.1b
F1.1.3			Plan loss of control procedure	GCS	C179	6.7.1c
F1.1.4			Plan navigation failure procedure	GCS	C180	6.7.1d
F1.1.5			Plan airframe damage procedure	GCS	C181	6.7.1e
F1.1.6			Plan autonomous recovery procedure	GCS		
F1.2		Command AV				
F1.2.1			Command orbit manueuvre	GCS	C72	5.10.4
F1.2.2			Command autonomous recovery	GCS	C220 C270	8.2.2 8.5.11
F1.2.3			Command holding pattern	GCS		
F1.2.4			Command AV attitude	GCS		
F1.2.5			Command AV propulsion system	GCS		
F1.2.6			Command AV navigation system	GCS		
F1.2.7			Command AV systems	GCS		
F1.2.8			Command AV position lights	GCS		
F1.2.9			Command AV anti-collision lights	GCS		
F1.2.10			Command transponder power	GCS		
F1.2.11			Select SSR code	GCS	C68 C71 C91 C137 C283	5.10.3 5.10.4 5.13.1 5.16.1c 8.6.1c
F1.2.12			Command SSR identification squawk	GCS		
F1.3		Display AV information			C140 C213	5.16.2 8.2.1
F1.3.1			Display flight	GCS	C95	5.13.4

(a) ID	(b) Functions - level 1	(c) Functions - level 2	(d) Functions - level 3	(e) Allocated To	(f) Reqt ID	(g) Reqt Para
			plan			
F1.3.2			Display AV attitude	GCS	C140 C262	5.16.2 8.5.9
F1.3.3			Display AV navigation	GCS	C262	8.5.9
F1.3.4			Display AV propulsion	GCS	C262	8.5.9
F1.3.5			Display AV systems	GCS	C262	8.5.9
F1.3.6			Display AV sensors	GCS	C262	8.5.9
F1.3.7			Display data link failure warning	GCS	C67	5.10.3
F1.3.8			Display data link range cues	GCS	C252	8.5.6
F1.3.9			Display degraded mode alerts	GCS	C216	8.2.1
F1.3.10			Display AV health status	GCS	C217 C296	8.2.1 8.6.1h
F1.3.11			Display AV failure warnings	GCS	C233	8.5.2
F1.3.12			Display AV power reserve	GCS	C299	8.6.1h
F1.3.13			Display transponder power state	GCS		
F1.3.14			Display SSR code	GCS		
F1.4		Display ground system information				
F1.4.1			Display flight recorder status	GCS	C262	8.5.9
F1.4.2			Display voice recorder	GCS	C262	8.5.9
F1.5		Control ground system				
F1.5.1			Control flight system recorder	GCS	C262	8.5.9
F1.5.2			Control voice recorder	GCS	C262	8.5.9
F1.5.3			Manage electrical loads	GCS	C249	8.5.5
F2	Provide data link communications				C218	8.2.1
F2.1		Monitor data link signal strength		DLS	C252	8.5.6
F2.2		Transmit uplink		DLS		
F2.3		Receive uplink		DLS		
F2.4		Transmit downlink		DLS		
F2.5		Receive downlink		DLS		
F3	Operate AV					

(a) ID	(b) Functions - level 1	(c) Functions - level 2	(d) Functions - level 3	(e) Allocated To	(f) Reqt ID	(g) Reqt Para
F3.1		Provide high-level control				
F3.1.1			Execute autonomous recovery	AVS	C62 C68 C183 C220 C270	5.10.1a 5.10.3 6.7.2a 8.2.2 8.5.11
F3.1.2			Execute engine failure procedure	AVS	C177	6.7.1a
F3.1.3			Execute lost data link procedure	AVS	C60 C178	5.10.1 6.7.1b
F3.1.4			Execute lost control procedure	AVS	C179	6.7.1c
F3.1.5			Execute navigation failure procedure	AVS	C180	6.7.1d
F3.1.6			Execute airframe damage procedure	AVS	C181	6.7.1e
F3.1.7			Fly holding pattern	AVS	C55	5.9.3
F3.1.8			Fly to recovery point	AVS	C62 C183	5.10.1a 6.7.2a
F3.1.9			Fly orbit manoeuvre	AVS		
F3.2		Control AV			C213	8.2.1
F3.2.1			Control AV attitude	AVS	C262	8.5.9
F3.2.2			Control AV propulsion system	AVS	C262	8.5.9
F3.2.3			Control AV navigation system	AVS	C262	8.5.9
F3.2.4			Control AV systems	AVS	C262	8.5.9
F3.2.5			Control AV sensors	AVS	C262	8.5.9
F3.2.6			Control AV position lights	AVS	C277	8.6.1a
F3.2.7			Control AV anti-collision lights	AVS	C280	8.6.1b
F3.2.8			Control transponder power	AVS	C137 C283	5.16.1c 8.6.1c
F3.2.9			Squawk SSR identification	AVS	C91 C137 C283	5.13.1 5.16.1c 8.6.1c
F3.2.10			Squawk lost link code	AVS	C68	5.10.3
F3.2.11			Set SSR code	AVS		
F3.3		Monitor AV				

(a) ID	(b) Functions - level 1	(c) Functions - level 2	(d) Functions - level 3	(e) Allocated To	(f) Reqt ID	(g) Reqt Para
		systems				
F3.3.1			Detect engine failure	AVS	C177	6.7.1a
F3.3.2			Detect loss of data link	AVS	C67 C68 C178	5.10.3 5.10.3 6.7.1b
F3.3.3			Detect loss of control	AVS	C179	6.7.1c
F3.3.4			Detect navigation failure	AVS	C180	6.7.1d
F3.3.5			Detect airframe damage	AVS	C181	6.7.1e
F3.3.6			Detect system failures	AVS	C233	8.5.2
F3.4		Manage electrical loads		AVS	C248	8.5.5
F4	Provide ATC communication s			GCS	C114	5.14.1b
F5	Test system functions					
F5.1		Provide diagnostic capability		AVS GCS DLS	C217	8.2.1
F5.2		Provide BIT		AVS GCS DLS	C296	8.6.1h
F6	Store data					
F6.1		Store AV status				
F6.1.1			Record AV status	GCS	C293	8.6.1g
F6.1.2			Erase AV status records	GCS		
F6.1.3			Replay AV status records	GCS		
F6.2		Store voice communication s				
F6.2.1			Record voice communication s	GCS	C293	8.6.1g
F6.2.2			Erase voice communication s records	GCS		
F6.2.3			Replay voice communication s records	GCS		
F6.3		Store flight plan				
F6.3.1			Save flight plan	AVS GCS		
F6.3.2			Delete flight plan	AVS GCS		
F6.3.3			Access flight plan	AVS GCS		

CHAPTER 13 APPENDIX 4: FUNCTION HIERARCHY DIAGRAMS

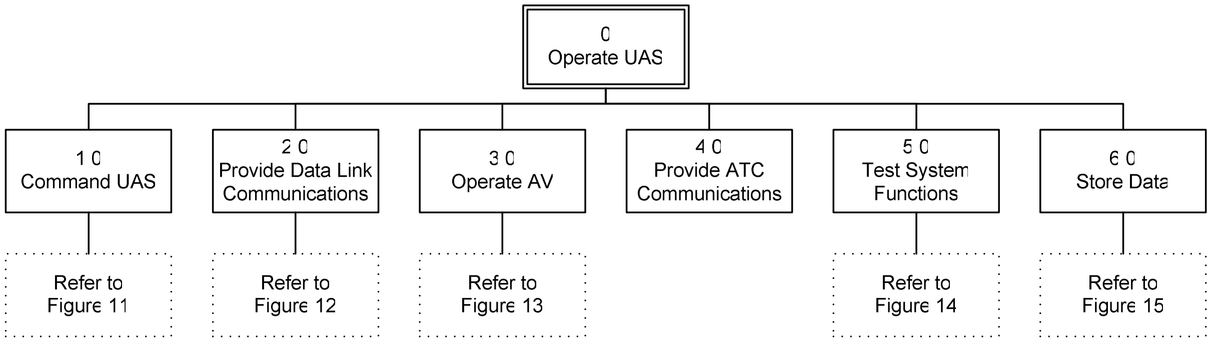

Figure 10 Function Hierarchy Down to Level 1

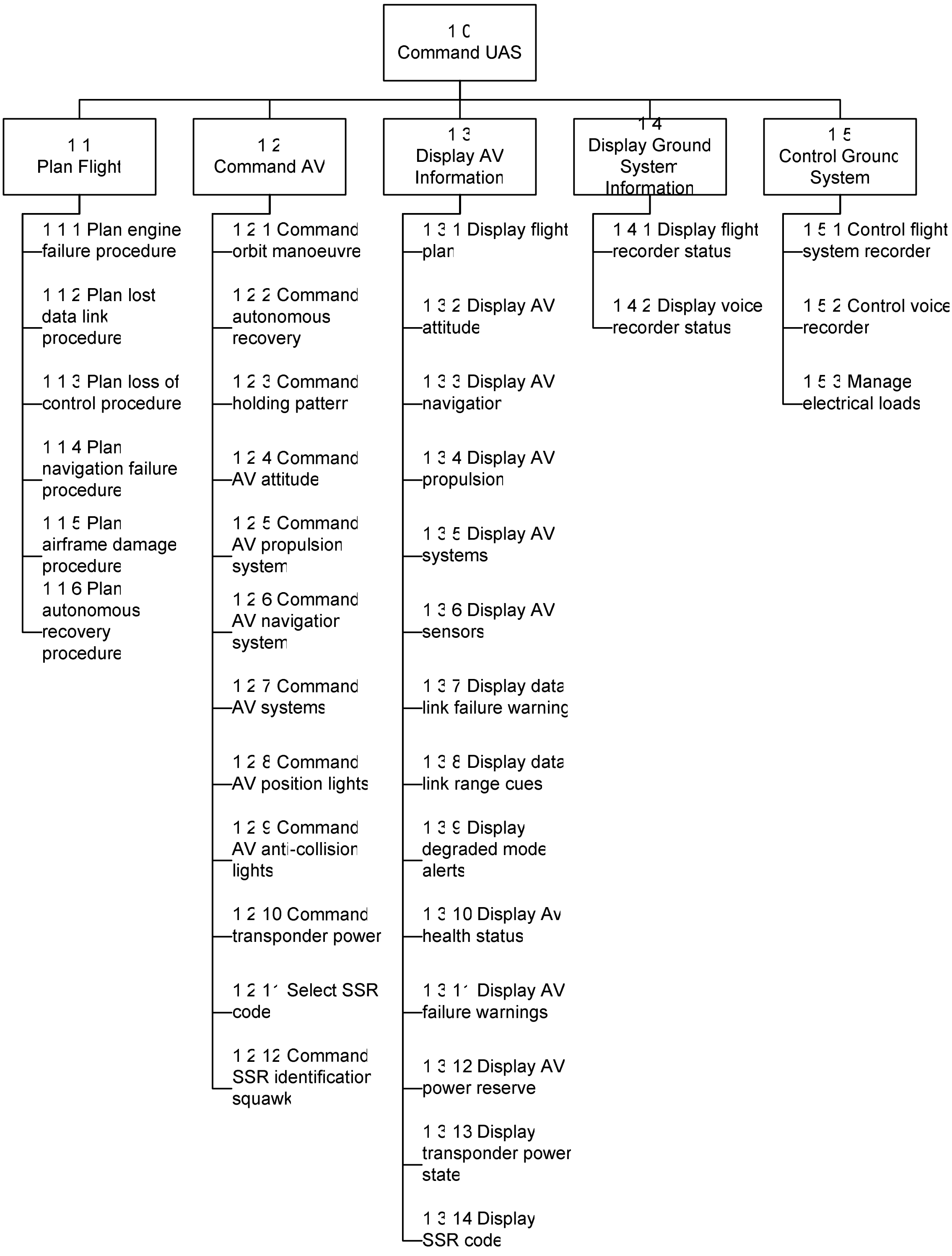

Figure 11 Function Hierarchy Below Function F1.0 “Command UAS”

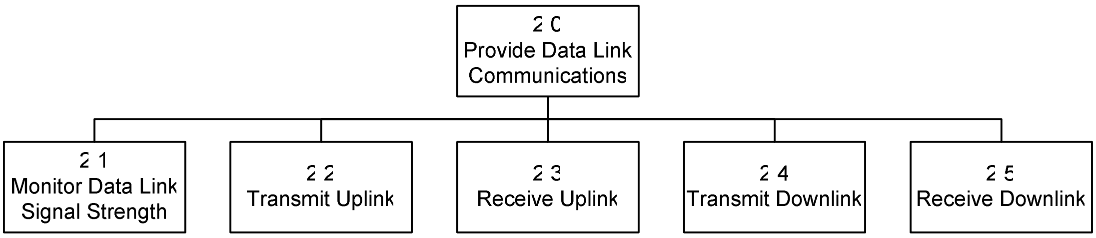

Figure 12 Function Hierarchy Below Function F2.0 "Provide Data Link Communications"

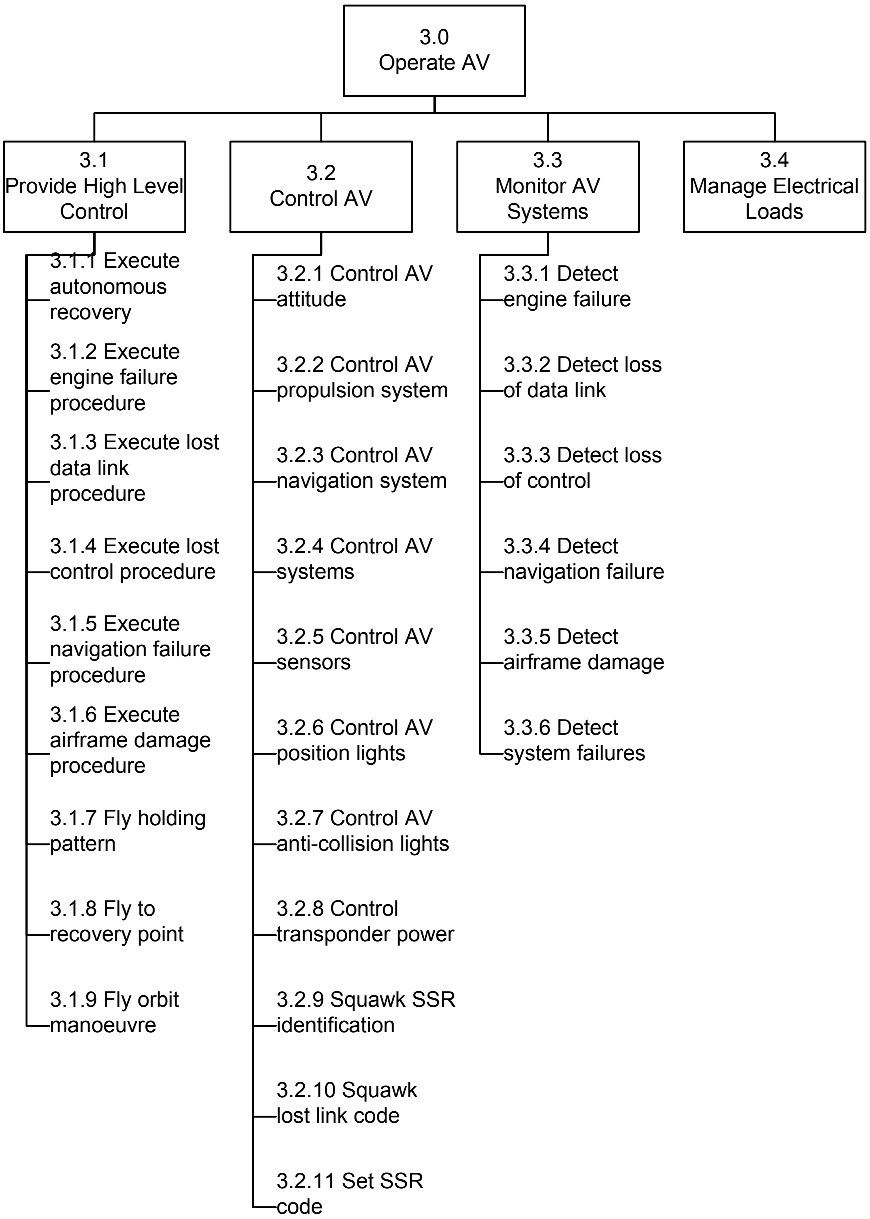

Figure 13 Function Hierarchy Below Function F3.0 "Operate AV"

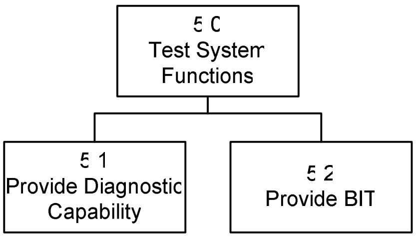

Figure 14 Function Hierarchy Below Function F5.0 "Test System Functions"

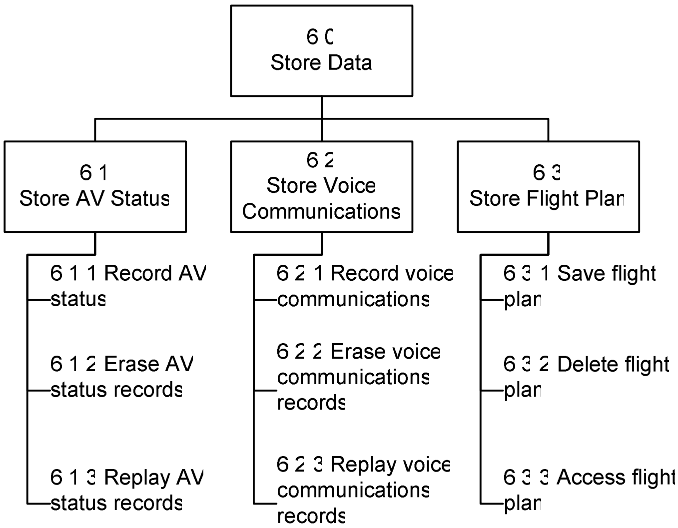

Figure 15 Function Hierarchy Below Function F6.0 "Store Data"

CHAPTER 14 APPENDIX 5: FUNCTIONAL FLOW DIAGRAMS

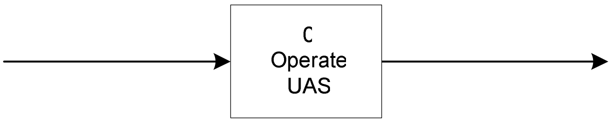

Figure 16. Top Level Functional Flow

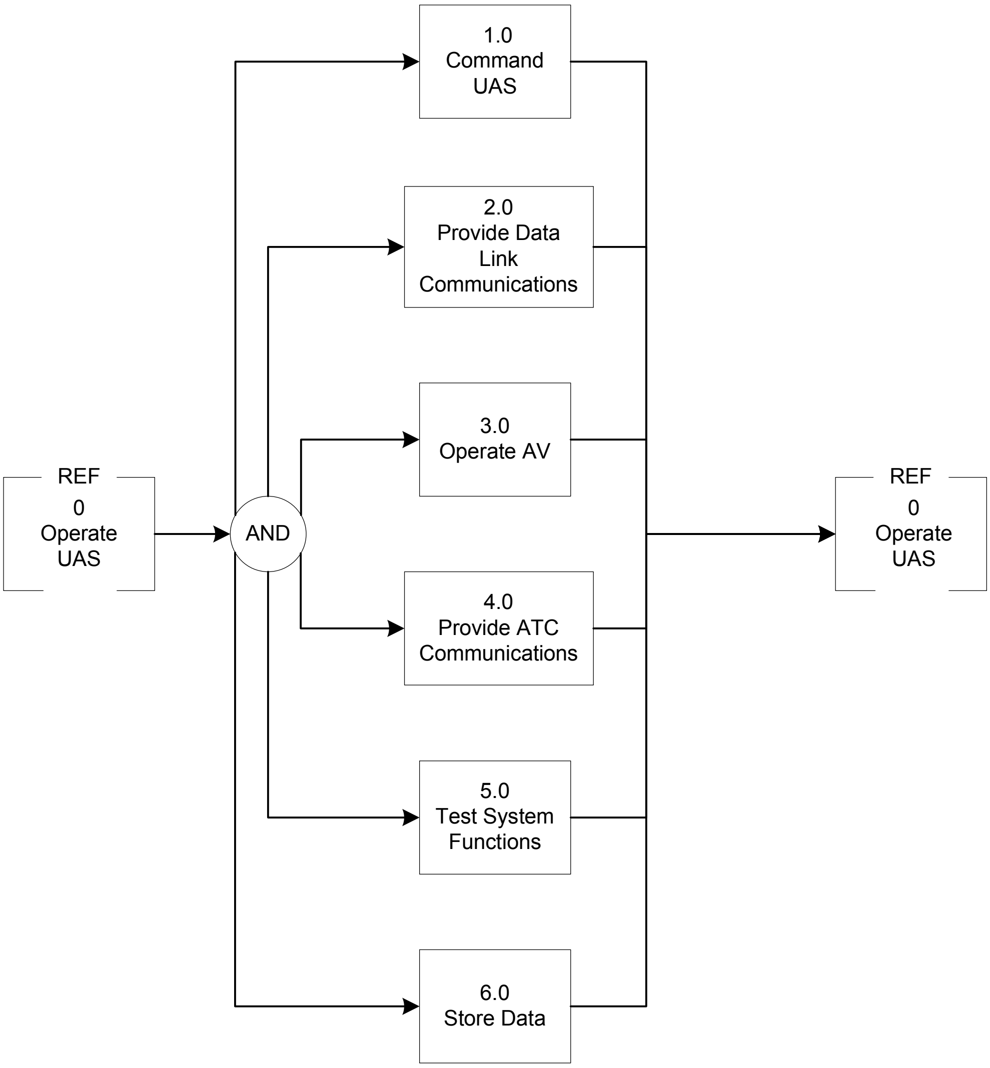

Figure 17. Functional Flow for Function 0 “Operate UAS”

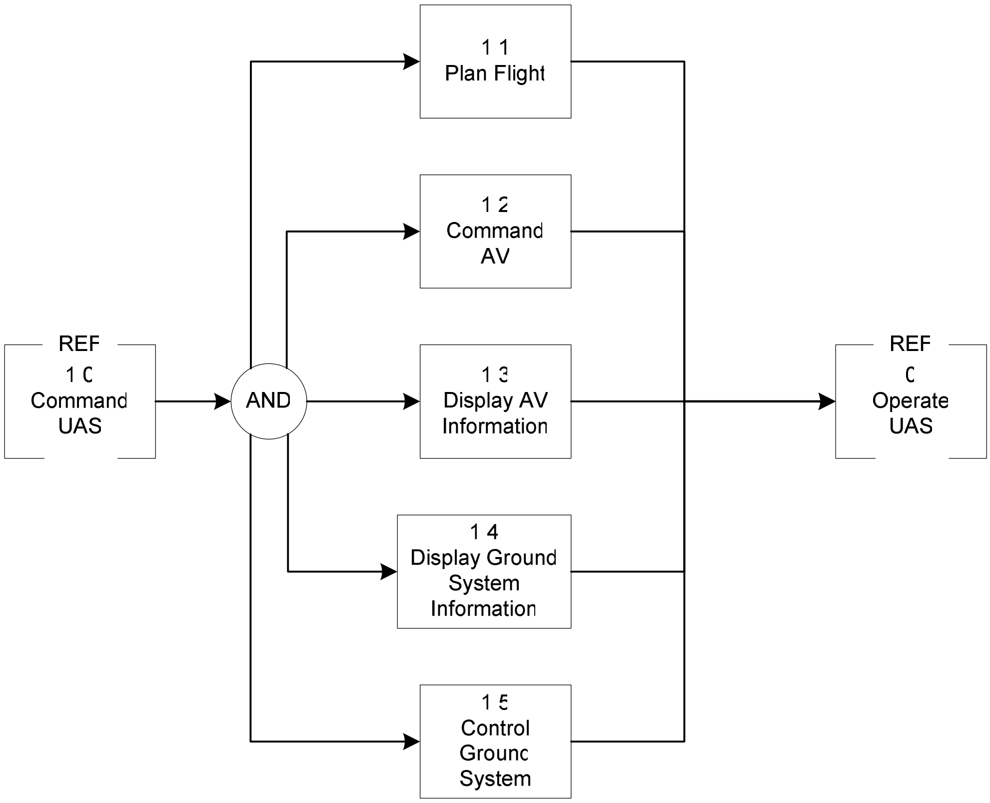

Figure 18. Functional Flow for Function 1.0 "Command UAS"

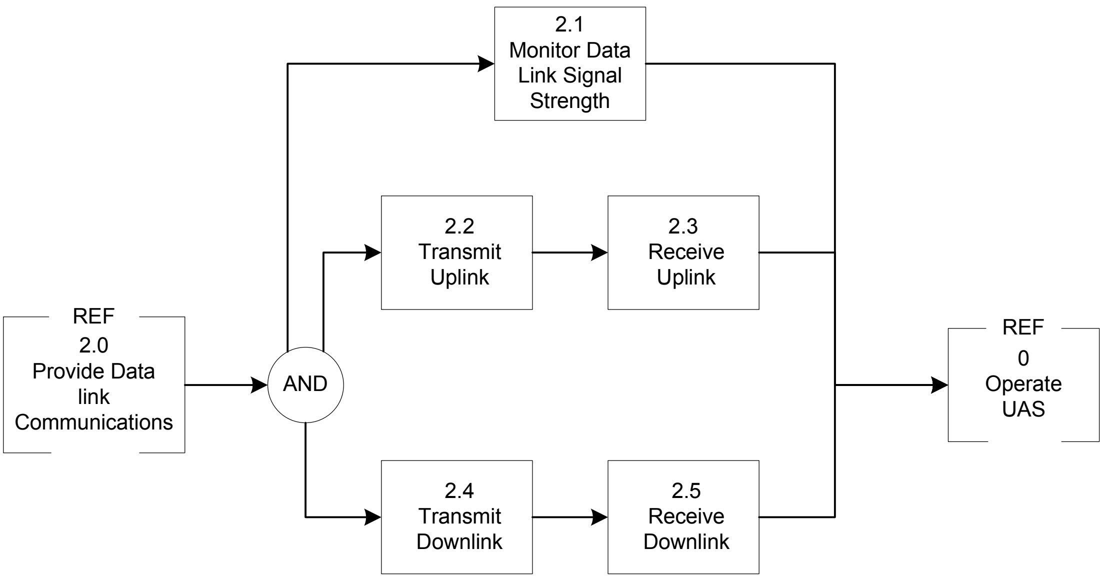

Figure 19. Functional Flow for Function 2.0 "Provide Data Link Communications"

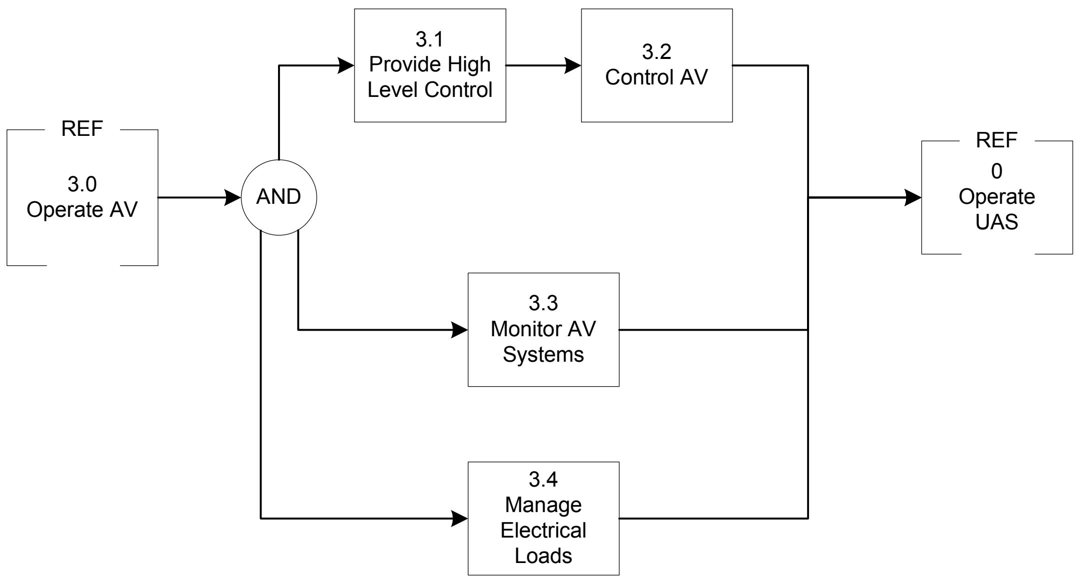

Figure 20. Functional Flow for Function 3.0 "Operate AV"

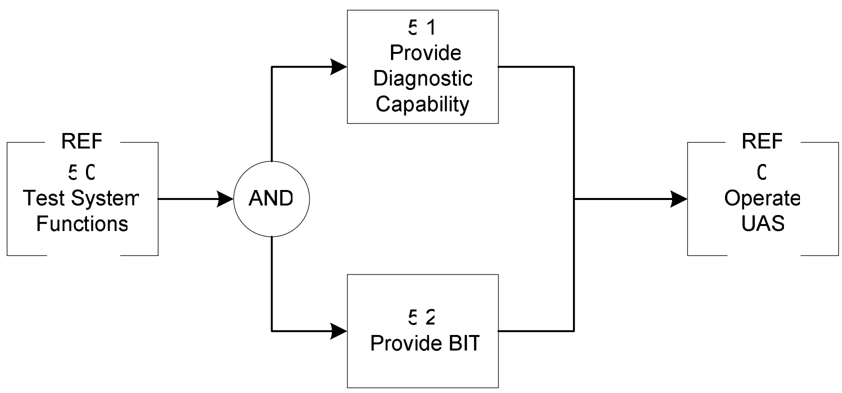

Figure 21. Functional Flow for Function 5.0 "Test System Functions"

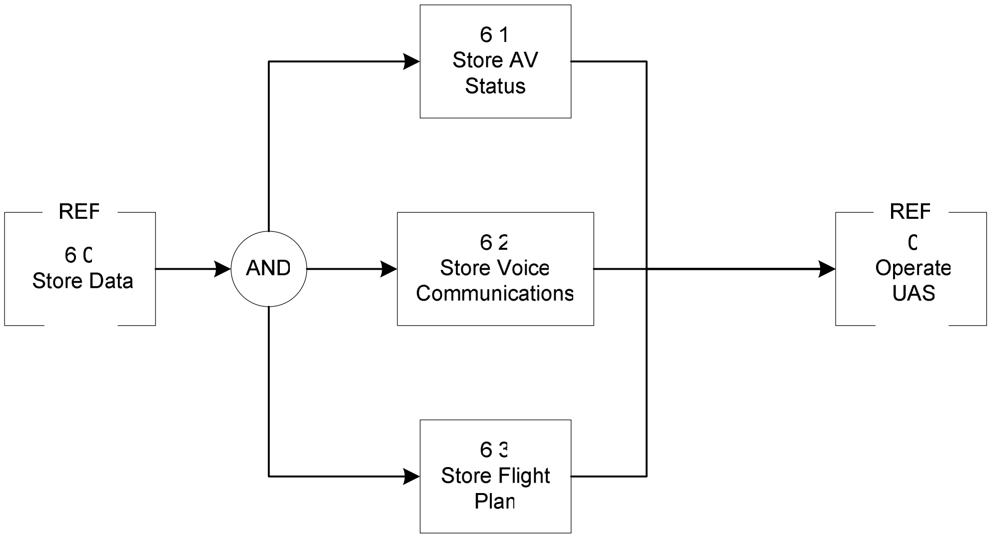

Figure 22. Functional Flow for Function 6.0 "Store Data"

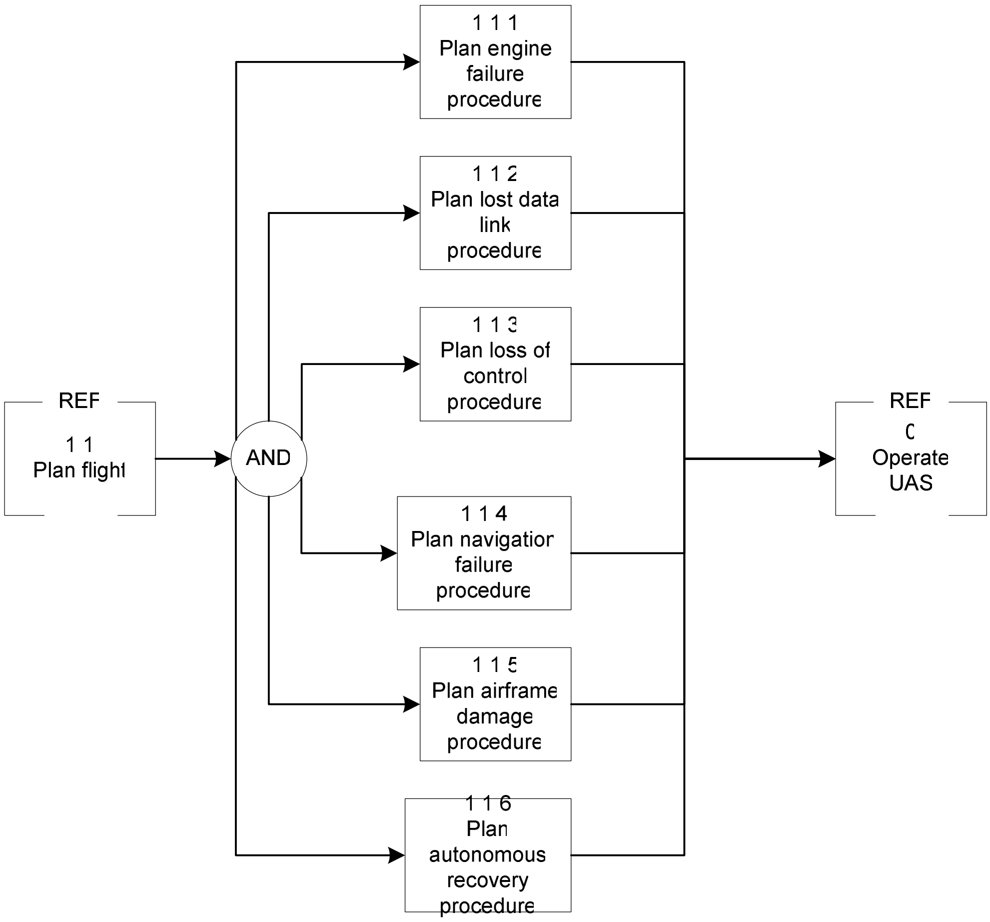

Figure 23 Functional Flow Diagram for Function 1.1 "Plan Flight"

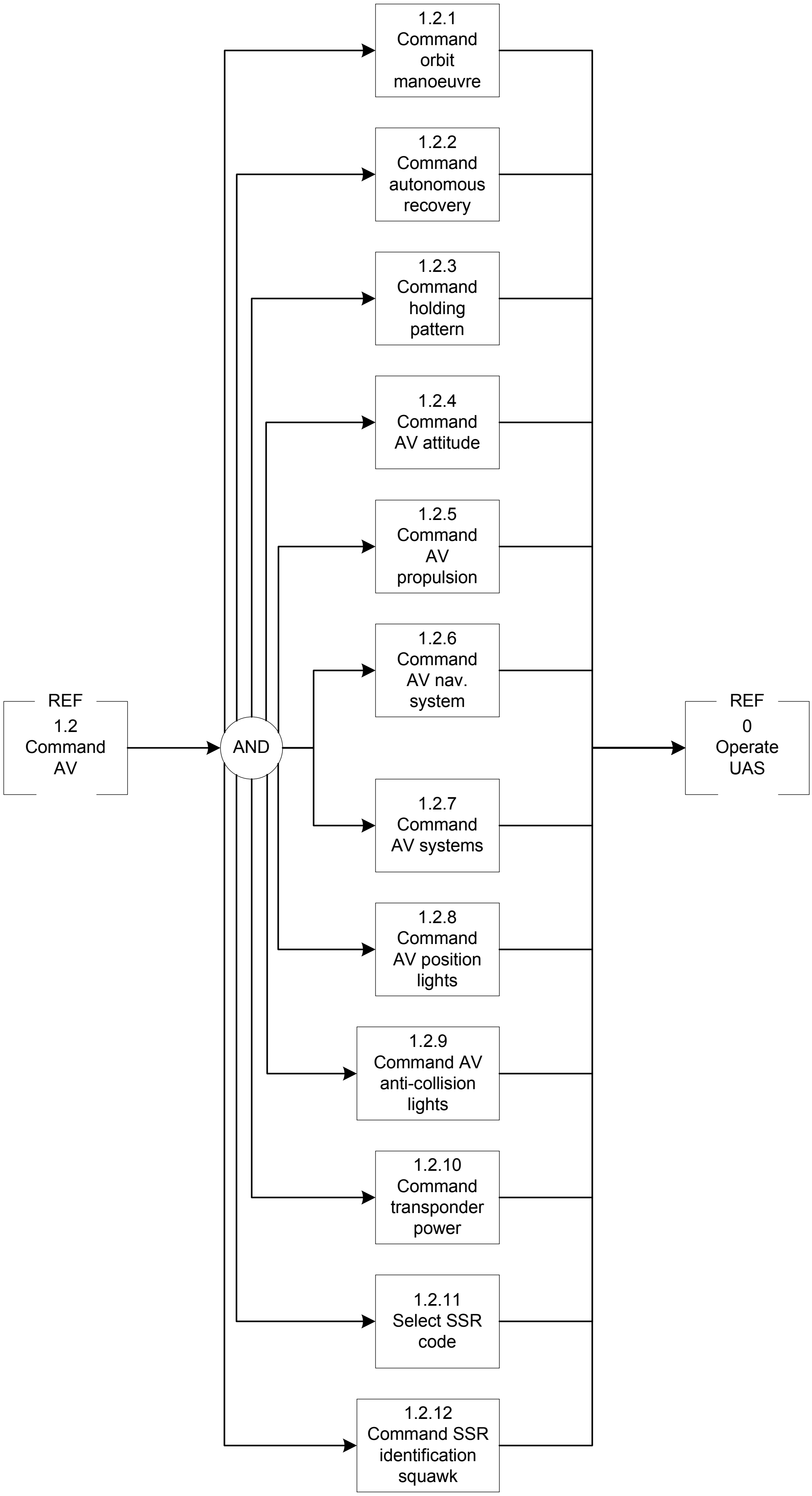

Figure 24 Functional Flow Diagram for Function 1.2 "Operate AV"

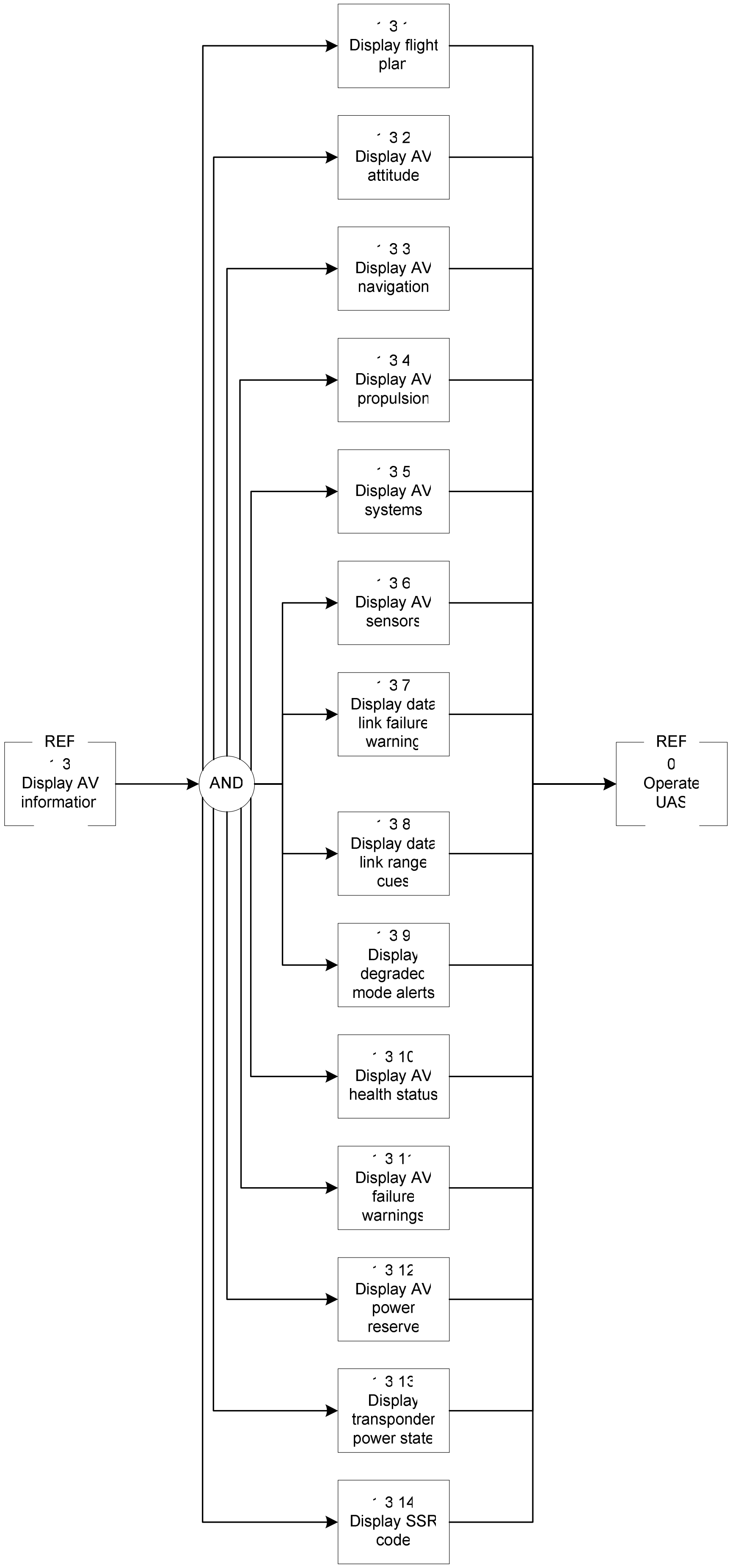

Figure 25 Functional Flow Diagram for Function 1.3 "Display AV Information"

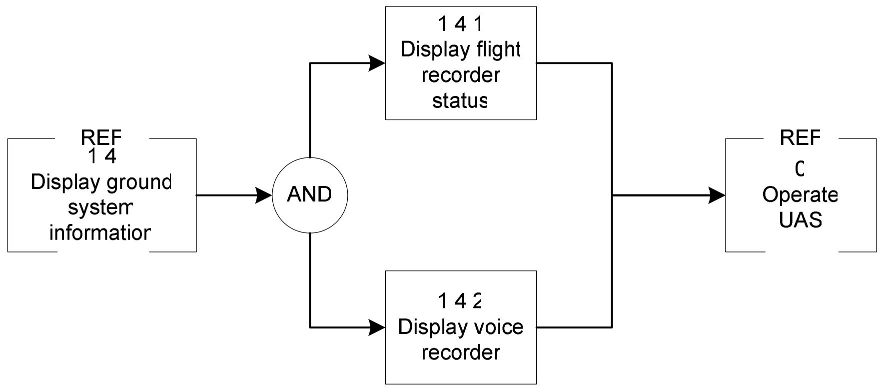

Figure 26 Functional Flow Diagram for Function 1.4 "Display Ground System Information"

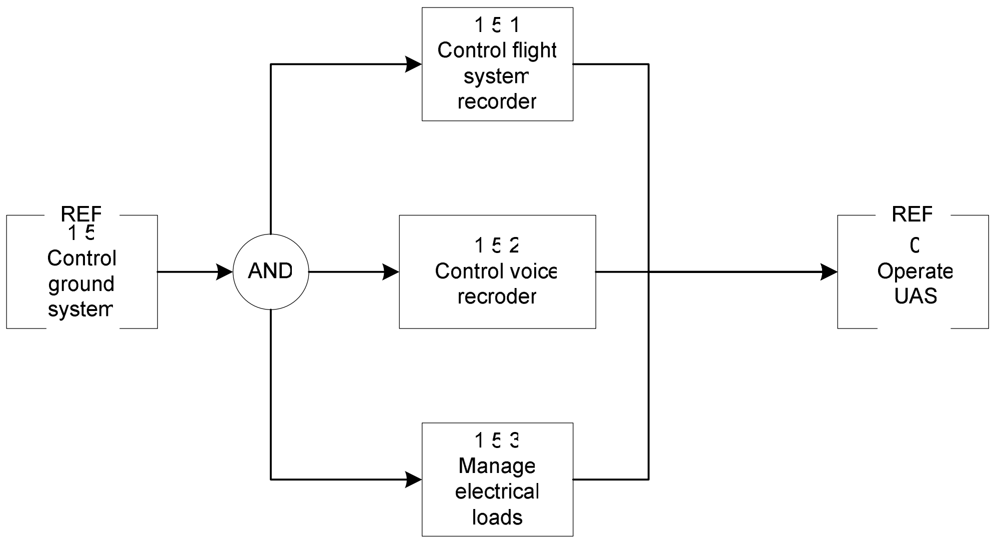

Figure 27 Functional Flow Diagram for Function 1.5 "Control Ground System"

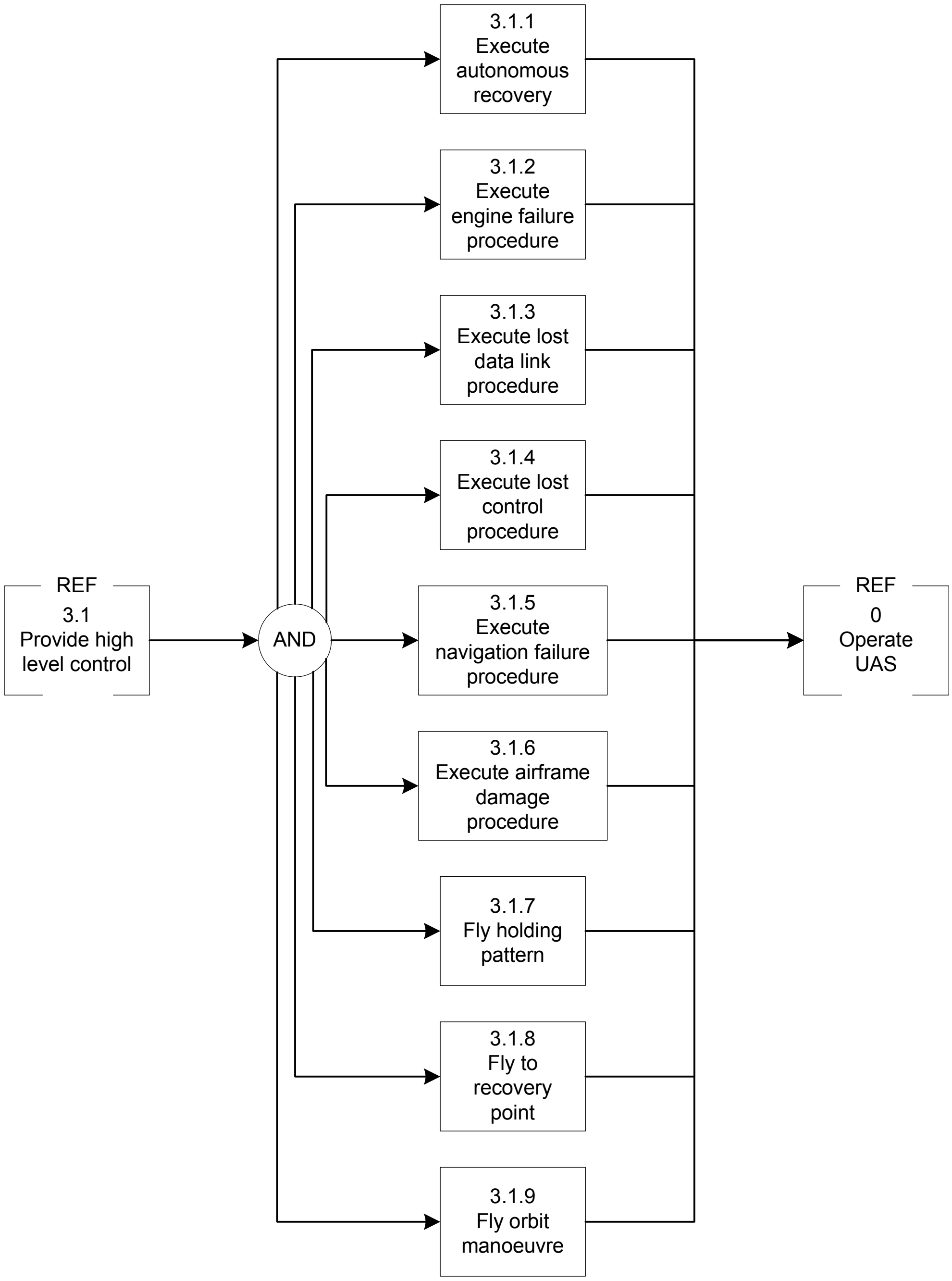

Figure 28 Functional Flow Diagram for Function 3.1 "Provide High Level Control"

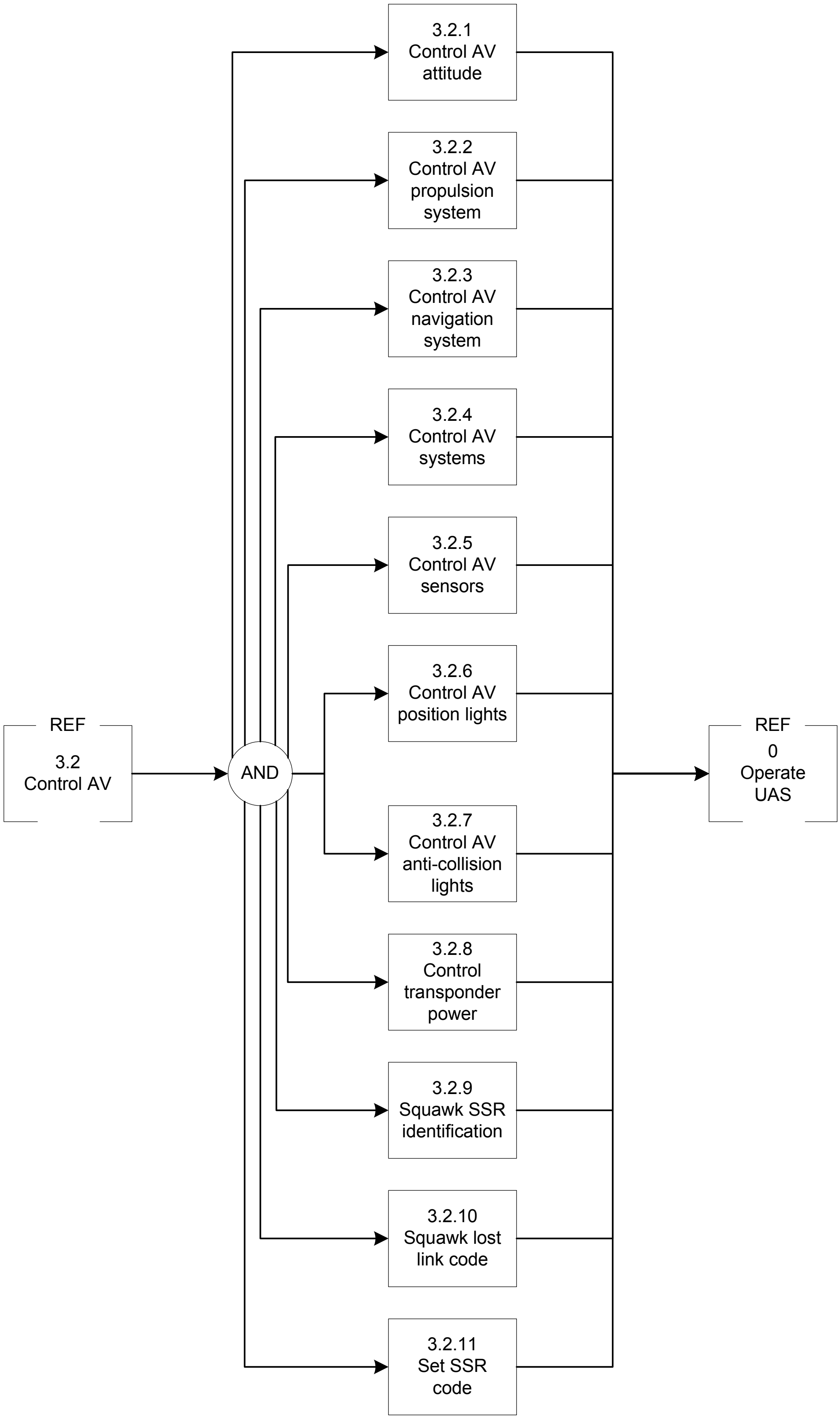

Figure 29 Functional Flow Diagram for Function 3.2 "Control AV"

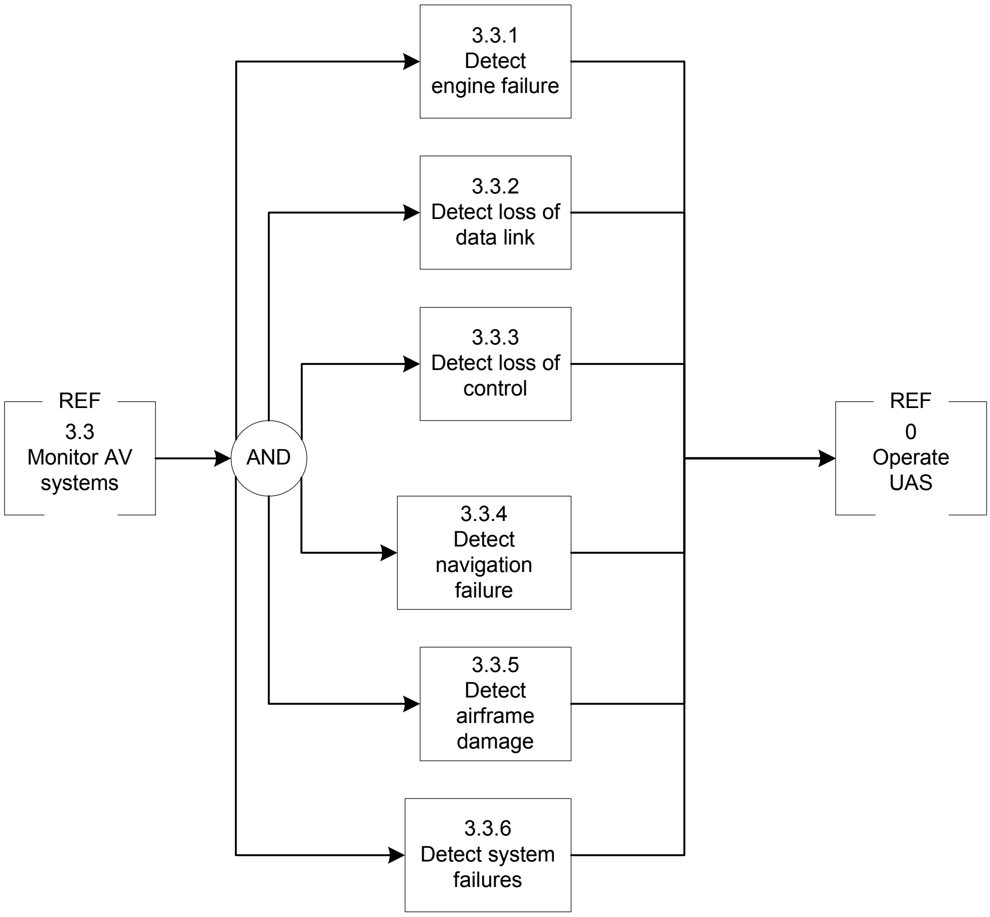

Figure 30 Functional Flow Diagram for Function 3.3 “Monitor AV Systems”

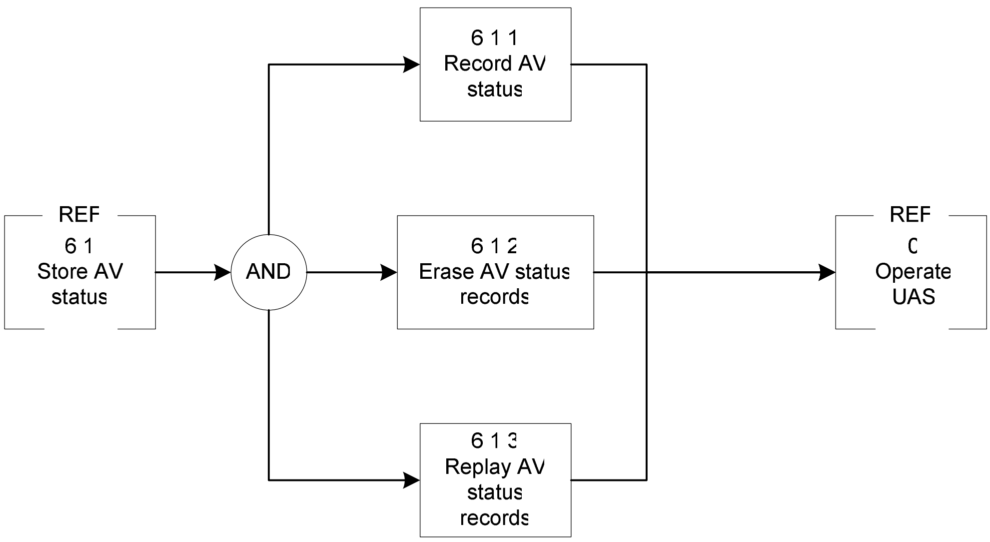

Figure 31 Functional Flow Diagram for Function 6.1 “Store AV Status”

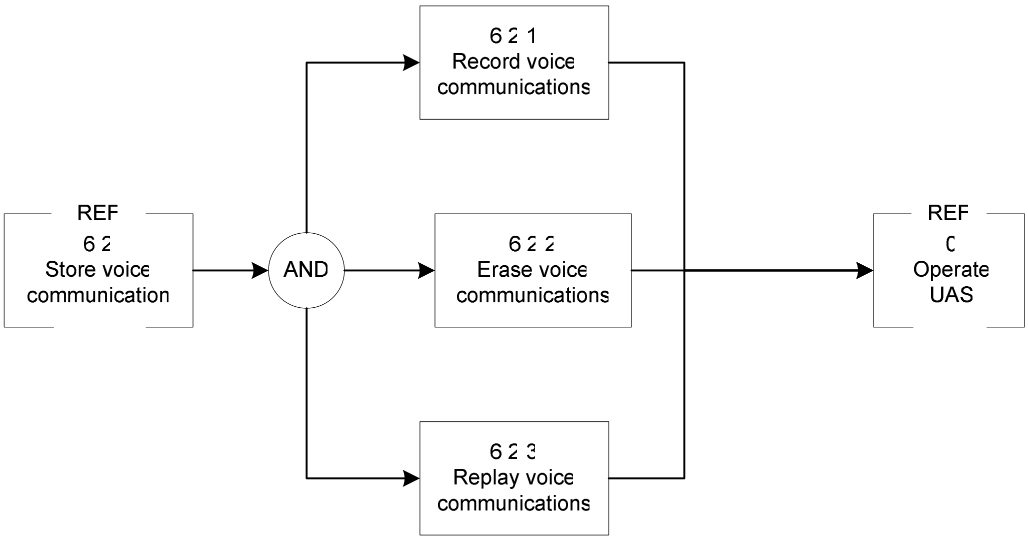

Figure 32 Functional Flow Diagram for Function 6.2 “Store Voice Communication”

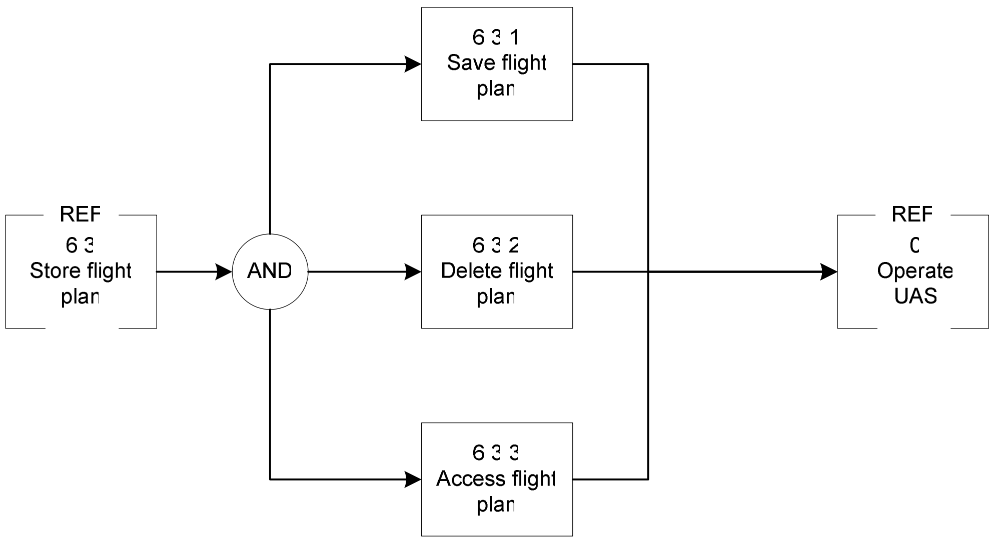

Figure 33 Functional Flow Diagram for Function 6.3 “Store Flight Plan”

CHAPTER 15 APPENDIX 6: SUBSYSTEM FUNCTIONAL REQUIREMENTS AND ALLOCATION

Table 5 Subsystem Functional Requirements and Allocation

(a) ID	(b) Functions	(c) System Allocation	(d) Subsystem Reqts	(e) Allocated To
F1	Command UAS			
F1.1	Plan flight		The GCS shall provide the capability to plan flights.	Mission Planner
F1.1.1	Plan engine failure procedure	GCS	The GCS shall provide the capability to specify a flight plan procedure to be executed in the event of engine failure.	Mission Planner
F1.1.2	Plan lost data link procedure	GCS	The GCS shall provide the capability to specify a flight plan procedure to be executed in the event of loss of data link communications.	Mission Planner
F1.1.3	Plan loss of control procedure	GCS	The GCS shall provide the capability to specify a flight plan procedure to be executed in the event of loss of control.	Mission Planner
F1.1.4	Plan navigation failure procedure	GCS	The GCS shall provide the capability to specify a flight plan procedure to be executed in the event of a navigation failure.	Mission Planner
F1.1.5	Plan airframe damage procedure	GCS	The GCS shall provide the capability to specify a flight plan procedure to be executed in the event of damage to the airframe.	Mission Planner
F1.1.6	Plan autonomous recovery procedure	GCS	The GCS shall provide the capability to specify a flight plan procedure to be executed to autonomously recover the AV.	Mission Planner
F1.2	Command AV			
F1.2.1	Command orbit manueuvre	GCS	The GCS shall provide the capability for the operator to command the AV to orbit a designated position.	Command Console
F1.2.2	Command autonomous recovery	GCS	The GCS shall provide the capability for the operator to command autonomous recovery of the AV.	Command Console
F1.2.3	Command holding pattern	GCS	The GCS shall provide the capability for the operator to command the AV to enter a holding pattern.	Command Console

F1.2.4	Command AV attitude	GCS	The GCS shall provide the capability for the operator to input AV attitude demands.	Command Console
F1.2.5	Command AV propulsion system	GCS	The GCS shall provide the capability for the operator to input AV propulsion system demands.	Command Console
F1.2.6	Command AV navigation system	GCS	The GCS shall provide the capability for the operator to input AV navigation system demands.	Command Console
F1.2.7	Command AV systems	GCS	The GCS shall provide the capability for the operator to input AV systems demands.	Command Console
F1.2.8	Command AV position lights	GCS	The GCS shall provide the capability for the operator to demand the AV position lights be on or off.	Command Console
F1.2.9	Command AV anti-collision lights	GCS	The GCS shall provide the capability for the operator to demand the AV anti-coliision lights be on or off.	Command Console
F1.2.10	Command transponder power	GCS	The GCS shall provide the capability for the operator to demand the AV transponder power be on or off.	Command Console
F1.2.11	Select SSR code	GCS	The GCS shall provide the capability for the operator to demand a selected SSR code.	Command Console
F1.2.12	Command SSR identification squawk	GCS	The GCS shall provide the capability for the operator to demand the SSR transponder squawk an identification.	Command Console
F1.3	Display AV information			
F1.3.1	Display flight plan	GCS	The GCS shall display the AV flight plan.	Command Console
F1.3.2	Display AV attitude	GCS	The GCS shall display the AV attitude.	Command Console
F1.3.3	Display AV navigation	GCS	The GCS shall display AV navigation information.	Command Console
F1.3.4	Display AV propulsion	GCS	The GCS shall display AV propulsion information.	Command Console
F1.3.5	Display AV systems	GCS	The GCS shall display AV systems information.	Command Console
F1.3.6	Display AV sensors	GCS	The GCS shall display AV sensor information.	Command Console
F1.3.7	Display data link failure warning	GCS	The GCS shall display a warning in the event of failure of the data link.	Command Console
F1.3.8	Display data link range cues	GCS	The GCS shall display range cues for the data link.	Command Console

F1.3.9	Display degraded mode alerts	GCS	The GCS shall display alerts when the system operates in a degraded mode.	Command Console
F1.3.10	Display AV health status	GCS	The GCS shall display the health status of the AV.	Command Console
F1.3.11	Display AV failure warnings	GCS	The GCS shall display warnings of AV failures.	Command Console
F1.3.12	Display AV power reserve	GCS	The GCS shall display the level of the AV power reserve.	Command Console
F1.3.13	Display transponder power state	GCS	The GCS shall display the power state of the AV transponder.	Command Console
F1.3.14	Display SSR code	GCS	The GCS shall display the Av transponder SSR code.	Command Console
F1.4	Display ground system information			
F1.4.1	Display flight recorder status	GCS	The GCS shall display the status of the flight data recorder.	Command Console
F1.4.2	Display voice recorder	GCS	The GCS shall display the status of the voice recorder.	Command Console
F1.5	Control ground system			
F1.5.1	Control flight system recorder	GCS	The GCS shall provide controls for the flight data recorder.	Command Console
F1.5.2	Control voice recorder	GCS	The GCS shall provide controls for the voice recorder.	Command Console
F1.5.3	Manage electrical loads	GCS	The GCS shall provide controls to manage electrical loads.	Power subsystem
F2	Provide data link communications			
F2.1	Monitor data link signal strength	DLS	The data link system shall monitor the signal strength of the data link.	GDT ADT
F2.2	Transmit uplink	DLS	The data link system shall transmit data from the GCS to the AV.	GDT
F2.3	Receive uplink	DLS	The data link system shall receive data transmitted to the AV from the GCS.	ADT
F2.4	Transmit downlink	DLS	The data link system shall transmit data from the AV to the GCS.	ADT
F2.5	Receive downlink	DLS	The data link system shall receive data transmitted to the GCS from the AV.	GDT
F3	Operate AV			
F3.1	Provide high-level control			
F3.1.1	Execute autonomous recovery	AVS	The AV shall be capable of autonomous recovery.	Avionics

F3.1.2	Execute engine failure procedure	AVS	The AV shall execute an engine failure procedure in the event of an engine failure.	Avionics
F3.1.3	Execute lost data link procedure	AVS	The AV shall execute a lost data link procedure in the event of loss of data link communications.	Avionics
F3.1.4	Execute lost control procedure	AVS	The AV shall execute a lost control procedure in the event of loss of control.	Avionics
F3.1.5	Execute navigation failure procedure	AVS	The Av shall execute a navigation failure procedure in the event of failure of the navigation system.	Avionics
F3.1.6	Execute airframe damage procedure	AVS	The Av shall execute an airframe damage procedure in the event of damage to the airframe.	Avionics
F3.1.7	Fly holding pattern	AVS	The AV shall fly a holding pattern on command.	Avionics
F3.1.8	Fly to recovery point	AVS	The AV shall fly to the specified recovery point on command.	Avionics
F3.1.9	Fly orbit manoeuvre	AVS	The AV shall fly an orbit manoeuvre on command.	Avionics
F3.2	Control AV			
F3.2.1	Control AV attitude	AVS	The AV shall control attitude in response to demands.	Avionics Airframe
F3.2.2	Control AV propulsion system	AVS	The AV shall control the propulsion system in response to demands.	Avionics Engine
F3.2.3	Control AV navigation system	AVS	The AV shall control the navigation system in response to demands.	Avionics
F3.2.4	Control AV systems	AVS	The AV shall control aircraft systems in response to demands.	Avionics Auxiliary systems
F3.2.5	Control AV sensors	AVS	The AV shall control aircraft sensors in response to demands.	Avionics
F3.2.6	Control AV position lights	AVS	The AV shall control position lights in response to demands.	Avionics Airframe
F3.2.7	Control AV anti-collision lights	AVS	The AV shall control anti-collision lights in response to demands.	Avionics Airframe
F3.2.8	Control transponder power	AVS	The AV shall control power to the transponder in response to demands.	Avionics
F3.2.9	Squawk SSR identification	AVS	The AV shall squawk SSR identification on command.	Avionics
F3.2.10	Squawk lost link code	AVS	The AV shall squawk the SSR lost communications code in the event of loss of data link communications.	Avionics

F3.2.11	Set SSR code	AVS	The AV shall set the SSR code as commanded.	Avionics
F3.3	Monitor AV systems			
F3.3.1	Detect engine failure	AVS	The AV shall detect engine failures.	Avionics Engine
F3.3.2	Detect loss of data link	AVS	The AV shall detect loss of data link communcations.	Avionics
F3.3.3	Detect loss of control	AVS	The AV shall detect loss of control.	Avionics Airframe
F3.3.4	Detect navigation failure	AVS	The AV shall detect failure of the navigation system.	Avionics
F3.3.5	Detect airframe damage	AVS	The AV shall detect damage to the airframe.	Avionics Airframe
F3.3.6	Detect system failures	AVS	The AV shall detect systems failures.	Avionics Auxiliary systems
F3.4	Manage electrical loads	AVS	The AV shall manage electrical loads.	Avionics Auxiliary systems
F4	Provide ATC communications	GCS	The GCS shall provide communications between the operator and ATC.	ATC Radio
F5	Test system functions			
F5.1	Provide diagnostic capability	AVS	The AV shall enable fault diagnosis.	all
F5.2	Provide BIT	AVS	The AV shall provide BIT.	all
F5.1	Provide diagnostic capability	GCS	The GCS shall enable fault diagnosis.	all
F5.2	Provide BIT	GCS	The GCS shall provide BIT.	all
F5.1	Provide diagnostic capability	DLS	The data link system shall enable fault diagnosis.	all
F5.2	Provide BIT	DLS	The data link system shall provide BIT.	all
F6	Store data			
F6.1	Store AV status			
F6.1.1	Record AV status	GCS	The GCS shall record AV status data.	Data Storage
F6.1.2	Erase AV status records	GCS	The GCS shall erase AV status data recrods on command.	Data Storage
F6.1.3	Replay AV status records	GCS	The GCS shall replay AV status data records on command.	Data Storage
F6.2	Store voice communications			
F6.2.1	Record voice communications	GCS	The GCS shall record voice communications.	Data Storage
F6.2.2	Erase voice communications records	GCS	The GCS shall erase voice communications records on command.	Data Storage
F6.2.3	Replay voice communications records	GCS	The GCS shall replay voice communicatiosn records on command.	Data Storage
F6.3	Store flight plan			
F6.3.1	Save flight plan	GCS	The GCS shall save the flight plan.	Data Storage

F6.3.2	Delete flight plan	GCS	The GCS shall delete a specified flight plan on command.	Data Storage
F6.3.3	Access flight plan	GCS	The GCS shall retrieve a specified flight plan on command.	Data Storage
F6.3.1	Save flight plan	AVS	The AV shall save the flight plan.	Avionics
F6.3.2	Delete flight plan	AVS	The AV shall delete a specified flight plan on command.	Avionics
F6.3.3	Access flight plan	AVS	The AV shall retrieve a specified flight plan on command.	Avionics