Detect & Avoid
Design, Test & Evaluation Guideline

Main Body

Version 1.0

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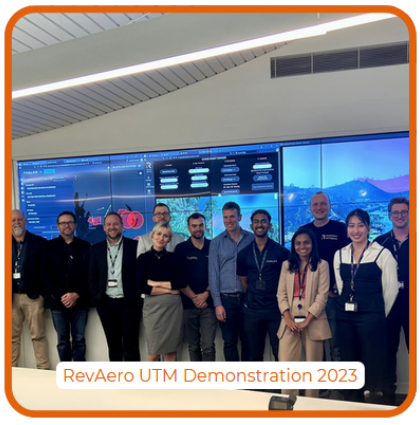

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Foreword

Revolution Aerospace is pleased to publish a Detect and Avoid (DAA) Design, Test and Evaluation (DT&E) Guideline (Version 1.0) for low-risk Uncrewed Aircraft System (UAS) operations in uncontrolled airspace outside the airport environment. An outline of the Guideline is provided in Figure 1 below.

This work was developed in partnership with Trusted Autonomous Systems (TAS) through initial funding by Queensland Government, and subsequently the Dept of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA) under the Emerging Aviation Technology Program.

The primary objective of Guideline 1.0 is to furnish regulators, DAA manufacturers, and Uncrewed Aircraft System (UAS) operators with a framework for approving or seeking approval for DAA systems tailored to the specifications outlined in the DAA DT&E Guideline Operational Services and Environmental Description (OSED).

A secondary, but important objective is that the suite of documents acts as a consolidating reference that draws together significant portions of research done by key bodies around the world including the Radio Technical Commission for Aeronautics (RTCA), ASTM International, Mitre, NASA, US Federal Aviation Administration (FAA), European Union Aviation Safety Agency (EASA), the Joint Authorities for Rulemaking on Unmanned Systems (JARUS) and the Massachusetts Institute of Technology (MIT). This work has underpinned significant portions of standards development, but it is often difficult for personnel new to the DAA environment to ascertain the rationale or basis for certain requirements that have evolved over time.

It is highlighted that Guideline 1.0 is provided for regulator consultation and public information only, while ongoing consultation with regulatory agencies – including the Civil Aviation Safety Authority (CASA) - is undertaken. It does not yet provide sufficient detail or information for regulators, DAA manufacturers, or UAS operators to approve, develop, or gain approval of a DAA system.

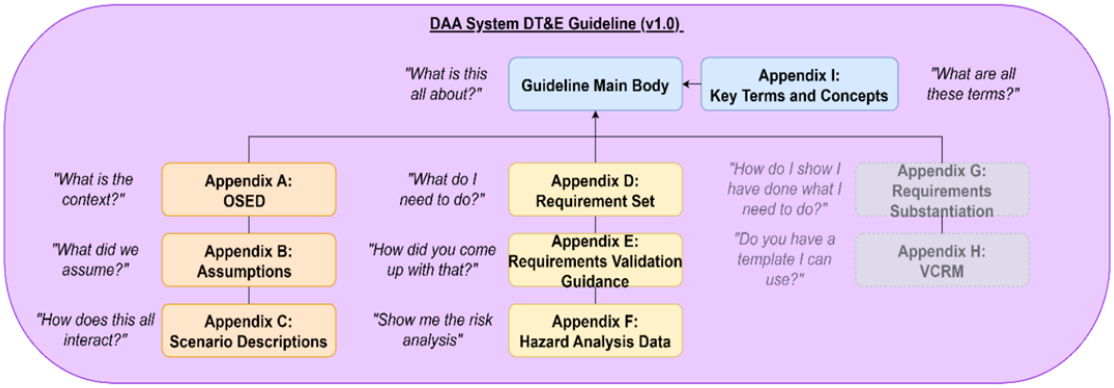

Figure 1: DAA DT&E Guideline Document Hierarchy

Background

Australia was the first country in the world to regulate drones and remains at the forefront of the future of drone regulation. Aerial taxis and drones are emerging aviation technologies with significant potential to disrupt the transport of people and products around the world. To realise this potential, these platforms need to operate Beyond Visual Line of Sight (BVLOS). Fundamental to that end-state is ensuring these platforms can be safely deconflicted which requires a combination of surveillance technologies and on-board Detect and Avoid (DAA).

Currently, enabling complex Uncrewed Aircraft Systems (UAS) operations requires that operators and the regulator conduct a labour-intensive multi-stakeholder consultation process identifying and mitigating the risks associated with mid-air collisions. Additionally, many operational limitations and overly conservative separation requirements are placed on the operation as UAS are unable to 'See and Avoid' other aircraft, like the pilot can. This approach is not scalable for the expected numbers of future UAS operations.

Why is consultation needed?

The delivery of Guideline 1.0 represents a significant step in support of future UAS operations in Australia, providing a common reference point for key stakeholders to support planning, awareness-raising and engagement. This is why Revolution Aerospace and TAS were eager to ensure public access to these resources now, even as further work remains to be done.

To this end, consultation with CASA and international regulatory agencies and organisations on Guideline 1.0 will ensure that any future iterations will represent best practice and provide an enduring, useable approach.

What next?

Feedback from regulatory consultation will enable consideration of appropriate next steps.

Opportunities to seek further information

If you would like further information on any part of the Guideline, you can do so by contacting Revolution Aerospace at founders@revn.aero

Development and Approvals

Developed	Approved
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Version History

Version	Release Date	Description
1.0	31 January 2024	Initial Release

Contributions

The Guideline has drawn on many different sources of DAA research, development, standardisation, and guidance material across the globe including information produced by the following organisations:

- RTCA
- ASTM
- JARUS
- FAA
- MIT
- EASA

Use and Licensing

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Attribution

When attributing this publication (and any material sourced from it), the following wording should be used:

References:

[1] T. Putland, A. McLaren, T. Martin, K. Cruickshank, Z. Huang, *"Detect & Avoid Design, Test & Evaluation Guideline-Main Body,"* Revolution Aerospace, Brisbane, Queensland, Australia, January 2024.

Acknowledgments:

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- Grant funding from the Australian Department of Infrastructure, Transport, Regional Development, Communications
- In-kind Support from the Queensland Government through Trusted Autonomous Systems (TAS), a Defence Cooperative Research Centre funded through the Commonwealth Next Generation Technologies Fund and the Queensland Government.

Disclaimer

Revolution Aerospace and Trusted Autonomous Systems accept no liability for the accuracy of this information, or the reliance placed upon it.

Contents

List of Figures

1 Introduction

The Detect and Avoid (DAA) Design, Test and Evaluation (DT&E) Guideline Version 1.0 marks the initial dissemination of foundational information that will serve as the basis for forthcoming iterations of the Guideline.

Figure 1 outlines the essential components envisaged for a comprehensive DAA DT&E Guideline. These components are designed to aid-end users in the pursuit of developing DAA systems that are tailored to specific needs, instilling confidence in aviation safety authorities regarding the implementation of appropriate DAA requirements that encompass all facets of the environment and aviation safety prerequisites.

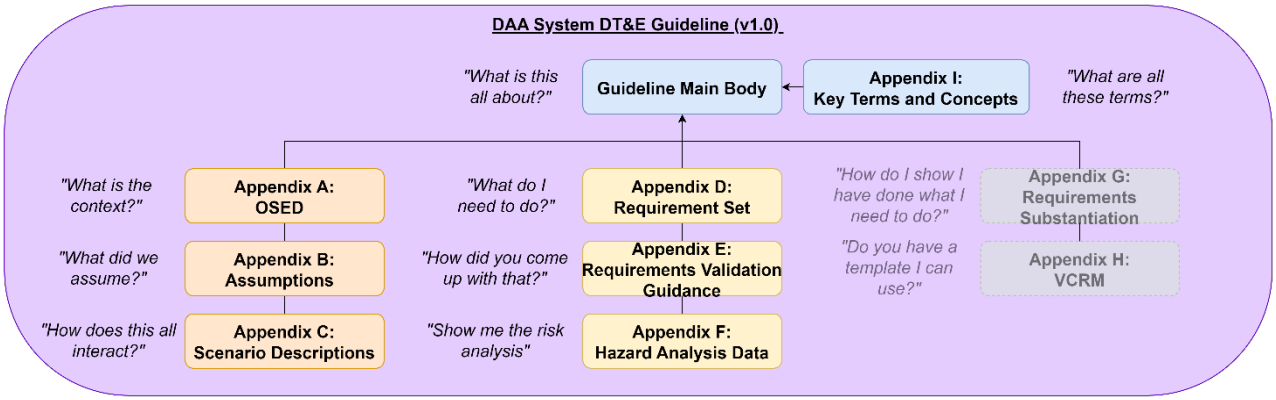

Figure 1: DAA DT&E Guideline Document Hierarchy

This release is specifically concentrated on Appendices A through F (inclusive of Appendix I), while the development of Appendices G and H is still ongoing. Nevertheless, by providing this partial set of documents to the UAS community, we aim to foster discussions, both domestically and internationally, pertaining to DAA performance requirements and verification. Revolution Aerospace and Trusted Autonomous Systems welcome feedback and commentary on this document.

2 Purpose

Once finalised, the DAA DT&E Guideline will empower the development and validation of a DAA system operating within Class G airspace, beyond the terminal environment, ensuring a satisfactory level of safety in accordance with the Specific Operation Risk Assessment (SORA) guidelines set by the Joint Authorities for Rulemaking on Unmanned Systems (JARUS) for DAA systems.

The guideline's primary objective is to furnish regulators, DAA manufacturers, and Uncrewed Aircraft System (UAS) operators with a framework for approving or seeking approval for DAA systems tailored to the specifications outlined in the DAA DT&E Guideline Operational Services and Environment Description (OSED).

A secondary, but important objective, is that the suite of document acts as a consolidating reference that draws together significant portions of research done by key bodies around the world including RTCA, ASTM, Mitre, NASA, FAA, EASA, JARUS, and MIT. Often, this work has underpinned significant portions of standards development, but it is often difficult for personnel new to the DAA environment to ascertain the rationale for certain requirements. This document suite helps to provide these linkages.

2.1 Existing DAA Standards

At the time this version of the Guideline was published, two pivotal standards governing the development and certification/approval of Detect and Avoid (DAA) systems existed. The motivation for the DAA DT&E Guideline differs against each of these standards.

1. RTCA DO-365C - Minimum Operational Performance Standards for Detect and Avoid Systems, 2022 [1]. This RTCA standard for DAA primarily targets large Unmanned Aircraft Systems, specifically those categorised as Group 4 and 5 by the US Department of Defense. It addresses significant Size, Weight, and Power requirements imposed by the necessary equipment to meet the standard. It should be noted that DO-365C specifies:

   > *"MOPS for DAA systems used in aircraft transiting and performing extended operations in Class D, E, and G airspace along with transiting Class B and C airspace. It includes equipment to enable UAS operations near Terminal Areas during approach and departure in Class C, D, E, and G airspace, and off-airport locations, but not operating in the visual traffic pattern or on the surface."*

   As such, it is not optimised for UAS operations intended for only a subset of that airspace (e.g. Class G outside the Terminal Environment) – hence a primary motivation for this Guideline.

2. ASTM F3442/F3442M - 20, Detect and Avoid System Performance Requirements, 2020 [2]. In contrast to DO-365C, ASTM F3442 applies to:

   > *"[UAS] with a maximum dimension (for example, wingspan, disc diameter) ≤25 ft, operating at airspeeds below 100 kts, and of any configuration or category. It is meant to be applied in a "lower risk" (low- and medium-risk airspace as described by Joint Authorities for Rulemaking on Unmanned Systems (JARUS)) airspace environment with assumed infrequent encounters with manned aircraft; this is typically in classes G and E airspace (below about 1200 ft above ground level (AGL)), Class B, C, D (below about 400 to 500 ft AGL), below obstacle clearance surface (FAA Order 8260.3, as amended), or within low altitude authorization and*

notification capability (LAANC) designated areas below the altitude specified in the facility map."

However, the ASTM standard provides minimal guidance on achieving the established requirements, lacks a clear description of the intended operating environment, and does not offer guidance or requirements for crucial technologies like Machine Learning, Artificial Intelligence, or Neural Networks, which are likely integral to DAA system development. Additionally, it does not prescribe encounter rates quantitatively.

Recognising the challenges associated with the identified limitations in the two aforementioned standards, the development of the DAA DT&E Guideline aims to address and overcome these challenges comprehensively.

2.2 Use of the Guideline

Version 1.0 of the DAA DT&E Guideline is provided for public consultation. It **does not** provide sufficient detail or information for regulators, DAA manufacturers, or UAS operators to approve, develop, or gain approval of a DAA system. The next version of the Guideline, taking into account any comments on version 1.0, is expected to be sufficient to achieve the purpose listed in Section 2.

3 Guideline Overview

This version of the Guideline is structured per Figure 1. The following subsections provide an overview of the expected content within each.

3.1 Main Body

This document is the Main Body. This provides an overarching structure to this Guideline, providing the necessary linkages between the Appendices. The overall reason for this Guideline existing is to show that using a Safety Risk Management (SRM) process, a Detect and Avoid equipped UAS can safely manage its airspace obligations within Uncontrolled Class G airspace). The components of a SRM process [3] are:

- **Contextualising the operation[1]:** Before any rational decisions can be made about risk, the following contexts need to be defined:
    - The risk and safety context, covering the expected level of safety for the given context (i.e. meeting aviation safety standards), and the level of rigour applied to mitigations preventing hazards based on the hazard severity.
    - The context involved with the combination of the task (Operating a Beyond Visual Line of Sight, or BVLOS, UAS that can avoid air traffic)

[1] The FAA use the term "System Analysis" in Order 8040.4C, however the term System here can be confusing. The intent of this phrase is maintained through the use of the term "Contextualising the Task-Environment

within the operational environment (in this case operations in uncontrolled Class G Airspace outside of airport environments).

In this Guideline, **Appendices A, B, C and E** contextualise the operation for the purposes of undertaking an acceptable risk management process.

- **Identify Hazards:** Once the context has been set, all reasonable hazards need to be identified through some rigorous, complete hazard identification process. **Appendix E** identifies the relevant hazards (operational and functional) that are further analysed in **Appendix F**.
- **Analyse Safety Risk:** After the identification of hazards, the next step is to analyse the risk of those hazards occurring, using the risk and safety context derived earlier. **Appendix F** to this Guideline contains both an Operational Hazard Analysis, and a Functional Hazard Analysis, which form the basis for all derived requirements throughout this Guideline.
- **Control Safety Risk:** Given the identified hazards and assessed risk, controls and mitigations need to be applied to manage the risk in accordance with the risk and safety context. The derivation of safety requirements necessary to meet the analysed safety risk is undertaken in **Appendix E**, with the final list of requirements summarised in **Appendix D**. To demonstrate that these requirements have been satisfied appropriately, future versions of this Guideline will include means of compliance within **Appendix G**, as well as a verification cross reference matrix template in **Appendix H**.

3.2 Appendix A – Operational Services and Environment Description (OSED)

The objective of this Appendix is to precisely delineate the operational framework for DAA-Equipped Unmanned Aircraft Systems, a context for which the broader Guideline has been developed to support DAA system development.

The Operational Services and Environment Description outlines crucial elements of the UAS and its operating surroundings. It delves into the significant characteristics of these elements, exploring their impact on DAA system operation and their interactions with other airspace participants or pertinent stakeholders. In certain instances, assumptions have been necessitated to establish boundaries within the scope of possible operations and environments. These assumptions, identified and numbered as ASSUMP-OSED.XX throughout the OSED, are not intrinsic to the functioning of a DAA System.

While there may be instances where a DAA system operates in contexts deviating from these assumptions, they play a vital role in formulating the DAA requirement set and validating it in Appendix E. Consequently, if these assumptions conflict with a proposed operation, further investigation may be warranted to re-validate the requirement set or modify it to accommodate differences in the operational context.

The OSED also provides detailed depiction for an anticipated array of operational scenarios, encompassing both nominal and off-nominal situations, complete with a scenario and sequence diagram for each. The version of the OSED accompanying this Guideline is mature, anticipating only minor changes for any future versions.

Appendix B consolidates the assumptions from the OSED into a single list, while Appendix C presents the comprehensive scenario descriptions outlined in Section 12 of this Appendix.

3.3 Appendix B – Assumptions

Appendix B to this Guideline is intended to capture all the assumptions made in the OSED in a single repository.

3.4 Appendix C – Scenario Descriptions

Appendix C to this Guideline contains the full suite of 12 Nominal and 9 Off-Nominal Scenarios.

3.5 Appendix D – Requirement Set

Appendix D to this Guideline contains a summarised list of all requirements, and their rationale, driven by the requirements derivation process in Appendix E to this Guideline.

3.6 Appendix E – Requirements Derivation

This appendix serves as the foundation for the safety requirements embedded within the Guideline, forming an integral part of a comprehensive safety argument. While it does not encompass guidance on the verification of safety requirements, it offers robust rationale and validation for each specified requirement.

The document further elucidates the rationale behind derived requirements, ensuring a high level of requirements traceability. This support for an assurance argument demonstrates that the prescribed safety outcomes are attainable through adherence to the requirements listed in the Guideline's requirement set found in Appendix D. Consequently, this appendix is anticipated to play a key role in the safety case argument for the approval of Beyond Visual Line of Sight operations in uncontrolled Class G airspace, below 10,000 feet Above Mean Sea Level (AMSL), at an Altitude Reporting Code (ARC) of ARC-c.

It's essential to note that the primary objective of this document is not to furnish a complete safety argument for the design, production, and operation of a DAA-equipped Unmanned Aircraft System. Instead, it offers foundational safety rationale as a starting point for designers and operators seeking approval for a DAA system, ultimately supporting the safety of UAS operations equipped with such systems. The level of requirement decomposition is limited to the operational safety and functional levels, with any lower decomposition involving system implementation decisions beyond the scope of this Guideline. Manufacturers are likely to undertake further

decomposition of requirements into specific system implementations to create a functioning DAA System.

This Requirements Derivation, along with the resulting Requirements Set, has been crafted with reference to the Operational Services and Environment Description in Appendix A to the Guideline. It's crucial to emphasize that the derived requirements are valid only within the context of the OSED, and any deviations necessitate additional safety analysis to assess their impact. Subsequently, a re-validation or supplementation of the Requirement Set may be required in the face of such deviations.

3.7 Appendix F – Hazard Analysis Data

Appendix F contains the complete operational hazard analysis and functional hazard analysis undertaken as part of this Guideline. These analyses are provided in full to ensure complete transparency of the derived requirements, and to provide context and clarity for those with unique considerations, who may need to adjust the safety case in some shape or form.

3.8 Appendix G – Requirements Substantiation (not included in version 1.0)

This Appendix will prescribe a means of compliance with the DAA DT&E Guideline performance and integrity requirements. Where an 'applicant' can demonstrate how they have used Appendix B to comply with the requirements, the DAA system can be deemed compliant with the Guideline.

The Means of Compliance Guidance for Requirements provides expanded guidance across key functions and themes, including maintaining the Safety Argument validity, and means to demonstrate key DAA functions including detect, track, decide, command, execute, convey, monitor through System verification.

3.9 Appendix H – Verification Cross Reference Matrix (VCRM) (not included in version 1.0)

In conjunction with future Appendix G, Appendix H is intended to provide a verification cross reference matrix template that allows for ensuring the complete verification of the requirements derived in Appendix E.

3.10 Appendix I – Key Terms and Concepts

This document is intended to serve as a glossary for the specific important terms and concepts used throughout this guideline. Due to the rapidly evolving nature of the UAS space, and the multiple approaches to the same problem, terms with subtle but important differences in meaning between one portion of the community and another can have significant impacts on understanding of the overall safety case.

This document clarifies the specifics of such terms in an attempt to eliminate ambiguity.

4 Conclusion

This initial release, Version 1.0, of the DAA DT&E Guideline aims to furnish both the industry and regulators with insights into the underlying rationale for a set of safety and integrity requirements outlined in Appendices A, B, C, D, E, F, and I. These requirements are crucial for the operation of a Detect and Avoid System within the specified context.

Subsequent iterations planned by RevAero for this Guideline will seek to expand context and guidance, facilitating the development of a robust safety case. This case will be instrumental in securing approval for DAA systems within the parameters outlined in the Guideline.

5 References

[1] RTCA, “DO-365B Minimum Operational Performance Standards for Detect and Avoid Systems,” 2021.

[2] ASTM, “F3442/F3442M - 20, Detect and Avoid System Performance Requirements,” 2020.

[3] “FAA Order 8040.4C - Safety Risk Management Policy,” Federal Aviation Administration, 2023.