RTCA, Inc.
1150 18th Street NW, Suite 910
Washington, DC 20036
USA

Minimum Aviation System Performance Standards for C2 Link Systems Supporting Operations of Uncrewed Aircraft Systems in U.S. Airspace

RTCA DO-377B
December 14, 2023

Prepared by: SC-228
© 2023 RTCA, Inc.

Copies of this document may be obtained from

RTCA, Inc.
Telephone: 202-833-9339
Facsimile: 202-833-9434
Internet: www.rtca.org

Please visit the RTCA Online Store for document pricing and ordering information.

FOREWORD

This document was prepared by Special Committee 228 (SC-228) Uncrewed Aircraft Systems and approved by the RTCA Program Management Committee (PMC) on December 14, 2023.

RTCA, Incorporated is a not-for-profit corporation formed to advance the art and science of aviation and aviation electronic systems for the benefit of the public. The organization develops consensus-based recommendations on contemporary aviation issues. RTCA's objectives include, but are not limited to:

- Coalescing aviation system user and provider technical requirements in a manner that helps government and industry meet their mutual objectives and responsibilities;

- Analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;

- Developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of Minimum Operational Performance Standards (MOPS) for equipment and electronic systems that support aviation; and

- Assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization (ICAO) and the International Telecommunication Union (ITU) and other appropriate international organizations can be based.

The recommendations of RTCA are often used as the basis for government and private sector decisions as well as the foundation for many Federal Aviation Administration Technical Standard Orders (TSOs).

Since RTCA is not an official agency of the United States Government, its recommendations may not be regarded as statements of official government policy unless so enunciated by the United States Government organization or agency having statutory jurisdiction over any matters to which the recommendations relate.

DISCLAIMER

This publication is based on material submitted by various participants during the SC approval process. Neither the SC nor RTCA has made any determination whether these materials could be subject to valid claims of patent, copyright or other proprietary rights by third parties, and no representation or warranty, expressed or implied is made in this regard. Any use of or reliance on this document shall constitute an acceptance thereof "as is" and be subject to this disclaimer.

This Page Intentionally Left Blank

TABLE OF CONTENTS

1 PURPOSE AND SCOPE 1

1.1 Introduction and Purpose of Document 1
1.1.1 Introduction 1
1.1.2 Purpose 1
1.2 Scope of the Document 2
1.3 Structure of the Document 3
1.4 Relationship to International Civil Aviation Organization (ICAO) Documents 6
1.5 Aircraft Equipment Information Vulnerabilities 7
1.6 References 7

2 APPROACH AND METHODOLOGY 9

2.1 Document Development Process 9
2.2 Methodology 9
2.2.1 Operational Services and Environment Definition (OSED) 9
2.2.2 Operational Safety Assessment (OSA) 10
2.2.3 Operational Security Analysis 10
2.2.4 Operational Performance Assessment (OPA) 10
2.3 Key Terms 11
2.3.1 Use of Requirements and Recommendations and KeyWords 11
2.3.2 Assumptions 11
2.3.3 Mitigation Means 12
2.3.4 Requirements 12
2.3.5 Recommendations 13
2.4 References 13

3 SYSTEM REQUIREMENTS 15

3.1 Requirements and Traceability 15
3.1.1 Requirements Overview 15
3.1.2 Traceability 16
3.2 Definitions and Terminology 16
3.2.1 C2 Link System Definition, Key Functions and Performance Context 16
3.2.2 C2 Link System RLP in the Context of the C2 Link Specification and QoSR 18
3.2.3 Definition of Key Terms 19
3.3 Assumptions 21
3.3.1 Assumptions from the OSED 22
3.3.1.1 Operational Assumptions from the OSED 22
3.3.1.2 Technical Assumptions from the OSED 26
3.3.2 Assumptions from the OSA 28
3.3.2.1 Limitations to Scope and OSA General Assumptions 28
3.3.2.2 SPECIFIC Assumptions from the OSA (Also used for Existing Controls) 34
3.3.2.3 Automatic Takeoff and Landing System Assumptions from the OSA 38
3.4 Operational Requirements 40
3.5 Functional Requirements 42
3.5.1 C2 Link System Functional Requirements 42
3.5.2 Interworking Requirements to Support FR-2.1 44
3.5.3 Interworking Requirements to Support FR-2.2 48
3.5.4 Interworking Requirements to Support FR-2.3 52
3.6 Operational Hazards and Safety Objectives 54

3.6.1 SO for Conventional UAS FR-1 55
3.6.2 SO for Air Taxi UAS FR-2 68
3.7 Performance Requirements 77
3.7.1.2 Advanced Scenario 80
3.7.3 Conventional UAS – Surface, Takeoff and Landing Non-Towered 83
3.7.3.1 Baseline SCENARIO 83
3.7.4 Conventional UAS – Surface Takeoff And Landing, Towered 85
3.7.4.1 Baseline Scenario 85
3.7.5 Conventional UAS - Departure and Arrival, Non-Towered 87
3.7.6 Conventional UAS - Departure and Arrival, Towered 88
3.7.7 Conventional UAS - Transit/Extended Operations, Class A Airspace 89
3.7.8 Conventional UAS - Transit/Extended Operations, Class B, C, and E Airspace 90
3.7.9 Conventional UAS - Transit/Extended Operations, Class G Airspace 91
3.7.10 Conventional UAS -Transit/Extended Operations, Class Oceanic A Airspace 93
3.8 Security Requirements 103
3.9 UAS Level Recommendations 108

4 REQUIREMENTS VERIFICATION FOR C2 LINK SYSTEMS 113

4.1 Assumptions 113
4.2 Verification Test Plan and Procedures Content 113
4.2.1 Verification Methods 114
4.3 C2 Link System Performance Requirements Verification Test Plan 115
4.3.1 Detailed Pre-Approval Verification Plan 115
4.3.2 C2 Link System Availability Requirement Verification 115
4.3.3 C2 Link System Latency Requirement Verification 117
4.3.4 C2 Link System Continuity Requirement Verification 118
4.3.5 C2 Link System Integrity Requirement Verification 119
4.3.6 Post Implementation Monitoring of System Performance 119
4.4 C2 Link System Functional, Interworking and Security Requirements Verification 120
4.4.1 Test Configuration 120
4.4.2 Verification Test Procedures Format 120
4.4.2.1 Test_Procedure_Name – Nominal 120
4.4.2.1.1 Test_Procedure_Name.N01 120
4.4.2.2 Test_Procedure_Name – Non-Nominal 121
4.4.2.2.1 Test_Procedure_Name.X01 121
4.4.2.3 Test Action Definitions 121
4.4.3 C2 Link System Security Requirements Verification 121
4.4.3.1 UAS_C2_SER_TP_001 121
4.4.3.1.1 UAS_C2_SER_TP_001 – Nominal 122
4.4.3.1.1.1 UAS_C2_SER_TP_001_N01 122
4.4.3.1.2 UAS_C2_SER_TP_001 – Non-Nominal 122
4.4.3.1.2.1 UAS_C2_SER_TP_001_X01 122
4.4.3.1.2.2 UAS_C2_SER_TP_001_X02 123
4.4.3.2 UAS_C2_SER_TP_002 123
4.4.3.2.1 UAS_C2_SER_TP_002 – Nominal 124
4.4.3.2.1.1 UAS_C2_SER_TP_002_N01 124
4.4.3.2.2 UAS_C2_SER_TP_002 – Non-Nominal 124
4.4.3.3 UAS_C2_SER_TP_003 125
4.4.3.3.1 UAS_C2_SER_TP_003 – Nominal 125
4.4.3.3.1.1 UAS_C2_SER_TP_003_N01 125
4.4.3.3.1.2 UAS_C2_SER_TP_003_N02 126
4.4.3.3.2 UAS_C2_SER_TP_003 – Non-Nominal 126
4.4.3.4 UAS_C2_SER_TP_004 126

4.4.3.4.1 UAS_C2_SER_TP_004 – Nominal 127
4.4.3.4.1.1 UAS_C2_SER_TP_004_N01 127
4.4.3.4.2 UAS_C2_SER_TP_004 – Non-Nominal 127
4.4.3.5 UAS_C2_SER_TP_005 127
4.4.3.5.1 UAS_C2_SER_TP_005 – Nominal 128
4.4.3.5.1.1 UAS_C2_SER_TP_005_N01 128
4.4.3.5.2 UAS_C2_SER_TP_005 – Non-Nominal 128
4.4.3.6 UAS_C2_SER_TP_006 128
4.4.3.6.1 UAS_C2_SER_TP_006_N01 129
4.4.3.7 UAS_C2_SER_TP_007 129
4.4.3.7.1 UAS_C2_SER_TP_007 – Nominal 130
4.4.3.7.1.1 UAS_C2_SER_TP_007_N01 130
4.4.3.7.1.2 UAS_C2_SER_TP_007_N02 130
4.4.3.7.2 UAS_C2_SER_TP_007 – Non-Nominal 131
4.4.3.8 UAS_C2_SER_TP_008 131
4.4.3.8.1 UAS_C2_SER_TP_008 – Nominal 131
4.4.3.8.1.1 UAS_C2_SER_TP_008_N01 131
4.4.3.8.2 UAS_C2_SER_TP_008 – Non-Nominal 132
4.4.3.8.2.1 UAS_C2_SER_TP_008_X01 132
4.4.3.8.2.2 UAS_C2_SER_TP_008_X02 132
4.4.3.9 UAS_C2_SER_TP_009 133
4.4.3.9.1 UAS_C2_SER_TP_009 – Nominal 133
4.4.3.9.1.1 UAS_C2_SER_TP_009_N01 133
4.4.3.9.2 UAS_C2_SER_TP_009 – Non-Nominal 134
4.4.3.10 UAS_C2_SER_TP_010 134
4.4.3.10.1 UAS_C2_SER_TP_010 – Nominal 134
4.4.3.10.1.1 UAS_C2_SER_TP_010_N01 134
4.4.3.10.1.2 UAS_C2_SER_TP_010_N02 135
4.4.3.10.2 UAS_C2_SER_TP_010 – Non-Nominal 136
4.4.3.11 UAS_C2_SER_TP_011 136
4.4.3.11.1 UAS_C2_SER_TP_011 – Nominal 136
4.4.3.11.1.1 UAS_C2_SER_TP_011_N01 136
4.4.3.11.2 UAS_C2_SER_TP_011 – Non-Nominal 137
4.4.3.12 UAS_C2_SER_TP_012 137
4.4.3.12.1 UAS_C2_SER_TP_012 – Nominal 137
4.4.3.12.1.1 UAS_C2_SER_TP_012_N01 138
4.4.3.12.2 UAS_C2_SER_TP_012 – Non-Nominal 138
4.4.3.13 UAS_C2_SER_TP_013 138
4.4.3.13.1 UAS_C2_SER_TP_013 – Nominal 139
4.4.3.13.1.1 UAS_C2_SER_TP_013_N01 139
4.4.3.13.2 UAS_C2_SER_TP_013 – Non-Nominal 139
4.4.3.14 UAS_C2_SER_TP_014 139
4.4.3.14.1 UAS_C2_SER_TP_014 – Nominal 140
4.4.3.14.1.1 UAS_C2_SER_TP_014_N01 140
4.4.3.14.2 UAS_C2_SER_TP_014 – Non-Nominal 140
4.4.3.15 Security Requirements Verification Traceability Matrix 140
4.4.4 C2 Link System Functional and Interworking Requirements Verification 140
4.4.4.1 UAS_C2_IR_TP_001 140
4.4.4.1.1 UAS_C2_IR_TP_001 – Nominal 141
4.4.4.1.1.1 UAS_C2_IR_TP_001.N01 141
4.4.4.1.1.2 UAS_C2_IR_TP_001.N02 141
4.4.4.1.2 UAS_C2_IR_TP_001 – Non-Nominal 142
4.4.4.2 UAS_C2_IR_TP_002 142
4.4.4.2.1 UAS_C2_IR_TP_002 – Nominal 142

4.4.4.2.1.1 UAS_C2_IR_TP_002.N01 142
4.4.4.2.1.2 UAS_C2_IR_TP_002.N02 142
4.4.4.2.2 UAS_C2_IR_TP_002 – Non-Nominal 142
4.4.4.2.2.1 UAS_C2_IR_TP_002.X01 143
4.4.4.2.2.2 UAS_C2_IR_TP_002.X02 143
4.4.4.3 UAS_C2_IR_TP_003 143
4.4.4.3.1 UAS_C2_IR_TP_003 – Nominal 143
4.4.4.3.1.1 UAS_C2_IR_TP_003.N01 144
4.4.4.3.1.2 UAS_C2_IR_TP_003.N02 144
4.4.4.3.2 UAS_C2_IR_TP_003 – Non-Nominal 144
4.4.4.3.2.1 UAS_C2_IR_TP_003.X01 144
4.4.4.3.2.2 UAS_C2_IR_TP_003.X02 144
4.4.4.4 UAS_C2_IR_TP_004 144
4.4.4.4.1 UAS_C2_IR_TP_004 – Nominal 145
4.4.4.4.1.1 UAS_C2_IR_TP_004.N01 145
4.4.4.4.1.2 UAS_C2_IR_TP_004.N02 145
4.4.4.4.1.3 UAS_C2_IR_TP_004 – Non-Nominal 145
4.4.4.5 UAS_C2_IR_TP_005 145
4.4.4.5.1 UAS_C2_IR_TP_005 – Nominal 146
4.4.4.5.1.1 UAS_C2_IR_TP_005.N01 146
4.4.4.5.2 UAS_C2_IR_TP_005 – Non-Nominal 146
4.4.4.5.2.1 UAS_C2_IR_TP_005.X01 146
4.4.4.6 UAS_C2_IR_TP_006 146
4.4.4.6.1 UAS_C2_IR_TP_006 – Nominal 147
4.4.4.6.1.1 UAS_C2_IR_TP_006.N01 147
4.4.4.6.1.2 UAS_C2_IR_TP_006.N02 147
4.4.4.6.1.3 UAS_C2_IR_TP_006.N03 148
4.4.4.6.1.4 UAS_C2_IR_TP_006.N04 148
4.4.4.6.1.5 UAS_C2_IR_TP_006.N05 148
4.4.4.6.2 UAS_C2_IR_TP_006 – Non-Nominal 148
4.4.4.7 UAS_C2_IR_TP_007 148
4.4.4.7.1 UAS_C2_IR_TP_007 – Nominal 149
4.4.4.7.1.1 UAS_C2_IR_TP_007.N01 149
4.4.4.7.1.2 UAS_C2_IR_TP_007.N02 149
4.4.4.7.2 UAS_C2_IR_TP_007 – Non-Nominal 149
4.4.4.8 UAS_C2_IR_TP_008 149
4.4.4.8.1 UAS_C2_IR_TP_008 – Nominal 150
4.4.4.8.1.1 UAS_C2_IR_TP_008.N01 150
4.4.4.8.1.2 UAS_C2_IR_TP_008.N02 150
4.4.4.8.1.3 UAS_C2_IR_TP_008.N03 151
4.4.4.8.2 UAS_C2_IR_TP_008 – Non-Nominal 151
4.4.4.9 UAS_C2_IR_TP_009 151
4.4.4.9.1 UAS_C2_IR_TP_009 – Nominal 151
4.4.4.9.1.1 UAS_C2_IR_TP_009.N01 152
4.4.4.9.2 UAS_C2_IR_TP_009 – Non-Nominal 152
4.4.4.10 UAS_C2_IR_TP_010 152
4.4.4.10.1 UAS_C2_IR_TP_010 – Nominal 152
4.4.4.10.1.1 UAS_C2_IR_TP_010.N01 152
4.4.4.10.1.2 UAS_C2_IR_TP_010.N02 153
4.4.4.10.2 UAS_C2_IR_TP_010 – Non-Nominal 153
4.4.4.11 UAS_C2_IR_TP_011 153
4.4.4.11.1 UAS_C2_IR_TP_011 – Nominal 154
4.4.4.11.1.1 UAS_C2_IR_TP_011.N01 154
4.4.4.11.1.2 UAS_C2_IR_TP_011.N02 154

4.4.4.11.2 UAS_C2_IR_TP_011 – Non-Nominal 155
4.4.4.12 UAS_C2_IR_TP_012 155
4.4.4.12.1 UAS_C2_IR_TP_012 – Nominal 155
4.4.4.12.1.1 UAS_C2_IR_TP_012.N01 155
4.4.4.12.2 UAS_C2_IR_TP_012 – Non-Nominal 156
4.4.4.12.2.1 UAS_C2_IR_TP_012.X01 156
4.4.4.13 UAS_C2_IR_TP_013 156
4.4.4.13.1 UAS_C2_IR_TP_013 – Nominal 156
4.4.4.13.1.1 UAS_C2_IR_TP_013.N01 157
4.4.4.13.2 UAS_C2_IR_TP_013 – Non-Nominal 157
4.4.4.14 UAS_C2_IR_TP_014 157
4.4.4.14.1 UAS_C2_IR_TP_014 – Nominal 157
4.4.4.14.1.1 UAS_C2_IR_TP_014.N01 158
4.4.4.14.2 UAS_C2_IR_TP_014 – Non-Nominal 158
4.4.4.15 UAS_C2_IR_TP_015 158
4.4.4.15.1 UAS_C2_IR_TP_015 – Nominal 158
4.4.4.15.1.1 UAS_C2_IR_TP_015.N01 159
4.4.4.15.1.2 UAS_C2_IR_TP_015.N02 159
4.4.4.15.2 UAS_C2_IR_TP_015 – Non-Nominal 159
4.4.4.16 UAS_C2_IR_TP_016 159
4.4.4.16.1 UAS_C2_IR_TP_016 – Nominal 160
4.4.4.16.1.1 UAS_C2_IR_TP_016.N01 160
4.4.4.16.1.2 UAS_C2_IR_TP_016.N02 160
4.4.4.16.1.3 UAS_C2_IR_TP_016.N03 160
4.4.4.16.1.4 UAS_C2_IR_TP_016.N04 160
4.4.4.16.2 UAS_C2_IR_TP_016 – Non-Nominal 161
4.4.4.17 UAS_C2_IR_TP_017 161
4.4.4.17.1 UAS_C2_IR_TP_017 – Nominal 162
4.4.4.17.1.1 UAS_C2_IR_TP_017.N01 162
4.4.4.17.2 UAS_C2_IR_TP_017 – Non-Nominal 162
4.4.4.17.2.1 UAS_C2_IR_TP_017.X01 163
4.4.4.17.2.2 UAS_C2_IR_TP_017.X02 163
4.4.4.18 Interworking Requirements Verification Trace Matrix 163

5 MEMBERSHIP 165

APPENDIX A CONCEPT OF OPERATIONS A-1

A.1 INTRODUCTION A-1
A.2 STAKEHOLDERS A-2
A.2.1 UAS Operators A-2
A.2.1.1 Goals A-2
A.2.1.2 Constraints A-2
A.2.2 UAS Original Equipment Manufacturers (OEM) A-3
A.2.2.1 Goals A-3
A.2.2.2 Constraints A-3
A.2.3 Aircraft Maintenance And Repair Organizations (MRO) A-3
A.2.3.1 Goals A-3
A.2.3.2 Constraints A-4
A.2.4 Equipment Manufacturers A-4
A.2.4.1 Goals A-4
A.2.4.2 Constraints A-4
A.2.5 FAA Air Traffic Organization (ATO) A-4
A.2.5.1 Goals A-4

A.2.5.2 Constraints A-4
A.2.5.3 Airspace Classification A-5
A.2.6 FAA Aviation Safety Organization A-5
A.2.6.1 Goals A-6
A.2.6.2 Constraints A-6
A.2.7 Radio Frequency (RF) Frequency Management Organization A-7
A.2.7.1 Goals A-7
A.2.7.2 Constraints A-7
A.2.7.3 Approaches To Frequency Management For UAS Terrestrial System A-9
A.2.8 UAS Traffic Management Organization A-9
A.2.8.1 UAS Traffic Management A-9
A.2.8.1.1 Goals A-9
A.2.8.1.2 Constraints A-10
A.2.9 C2 Link System Communications Service Providers A-10
A.2.9.1 Goals A-10
A.2.9.2 Constraints A-11
A.2.10 International Civil Aviation Organization A-11
A.2.10.1 Goals A-11
A.2.10.2 Constraints A-11
A.2.11 International Telecommunications Union Radiocommunications Sector (ITU-R) A-11
A.2.11.1 Goals A-12
A.2.11.2 Constraints A-12
A.2.12 Provider Of Services (PSU) For Urban Air Mobility (UAM) A-12
A.3 LIFE CYCLE ASPECTS A-13
A.3.1 Development A-13
A.3.2 Operation A-14
A.3.3 Maintenance A-14
A.3.4 Disposal A-15
A.3.5 Life Cycle Costs A-15
A.3.6 Schedule A-15
A.3.7 Risk Management A-16
A.4 EXISTING OPERATIONAL CONDITIONS A-16
A.4.1 Basic Definitions A-16
A.4.2 Flight Phases Definitions A-17
A.4.3 Airspace Classes A-19
A.5 ASSESSMENT OF WHOLE UAS IMPACT ON C2 LINK SYSTEM A-22
A.5.1 Control The UA A-22
A.5.2 Avionics A-22
A.5.2.1 Flight Guidance System A-22
A.5.2.2 Flight Management System A-22
A.5.2.3 ATC Communication A-22
A.5.2.4 DAA A-23
A.5.2.5 Weather Radar A-23
A.5.2.6 UA Status Reporting System A-23
A.6 THE CONOPS DERIVATION A-24
A.6.1 Summary Of Key Aspects A-24
A.6.1.1 How Those Aspects Impact UAS Operations A-24
A.6.1.2 How Those Aspects Impact The C2 Link System A-25
A.6.2 Previous UAS Conops Efforts A-26
A.6.2.1 SC-203 Conops A-26
A.6.2.2 FAA Conops A-27
A.6.2.3 Earlier SC-228 Efforts A-27
A.6.3 Payload A-27
A.6.4 Derived Conops A-28

A.6.4.1 Selection Of The Conops In The Initial C2 Link System MASPS A-30
A.6.4.1.1 Local Linear Sensing Operations A-30
A.6.4.1.2 Local Area Operations A-31
A.6.4.1.3 Extended Aerial Operations A-31
A.6.4.1.4 High Altitude Long Endurance (HALE) Operations A-32
A.6.4.2 Relationship With DAA Conops Developments A-34
A.7 REFERENCES A-34

APPENDIX B OPERATIONAL SERVICES AND ENVIRONMENT DEFINITION (OSED) B-1

B.1 INTRODUCTION B-1
B.2 ENVIRONMENT B-4
B.2.1 Current FAA Regulations And Related Guidance B-4
B.2.2 Safety B-12
B.2.2.1 Introduction B-12
B.2.2.2 Safety Related FAA Rules B-13
B.3 SERVICES B-13
B.3.1 FAA Air Traffic Services (ATS) B-14
B.3.1.1 Data Services B-14
B.3.1.2 Voice Communications B-14
B.3.1.2.1 Introduction B-14
B.3.1.2.2 Current FAA ATS Ground Voice Communications Services B-14
B.3.1.2.3 Voice Communications Latency B-15
B.3.1.2.4 Future FAA Voice Communications Services B-15
B.3.1.2.5 Possible Architecture Alternatives B-15
B.3.1.2.5.1 Relay The Voice Communications Through The UA (Method 1) B-16
B.3.1.2.5.2 Ground To Ground Connectivity Directly Using The FAA Provided Voice Systems (Method 2) B-16
B.3.1.2.5.3 Ground-Based Remote Pilot Voice Radio (Method 3) B-16
B.3.2 Separation Service (ATS) B-17
B.3.3 C2 Link System Communication Service Providers B-17
B.3.3.1 SATCOM B-17
B.3.3.2 Terrestrial Services B-18
B.3.3.3 Connections Between The CS And The Ground Components Of Either SATCOM Or Terrestrial Services B-18
B.4 OPERATIONS – SPECIFIC SCENARIOS B-18
B.4.1 Operational And Technical Assumptions B-19
B.4.1.1 Operational Assumptions B-19
B.4.1.2 Technical Assumptions B-23
B.4.2 Conops 1, Local Linear Sensing Operations B-25
B.4.2.1 Power Line Scenario B-25
B.4.2.2 Overview B-25
B.4.2.3 Additional Assumptions For This Power Line Inspection Scenario B-26
B.4.2.4 Flight Profile B-26
B.4.2.5 Description Of The Scenario B-27
B.4.2.6 Use Cases B-27
B.4.2.7 Use Case Descriptions B-28
B.4.2.7.1 Use Case 0.1 (C1-S1-Uc0.1) Continuous Monitoring Of C2 Link System B-28
B.4.2.7.3 Use Case 0.3 (C1-S1-Uc0.3) Parameter Change Within The Ground/Ground Portion Of The C2 Link System B-29
B.4.2.7.5 Use Case 1 (C1-S1-Uc1) - Pre-Flight/Takeoff B-30
B.4.2.7.6 Use Case 2 (C1-S1-Uc2) B-30
B.4.2.7.7 Use Case 3 (C1-S1-Uc3) – DAA Event B-31
B.4.2.7.8 Use Case 4 (C1-S1-Uc4) – ATC Vectors B-31

B.4.2.7.9 Use Case 5 ..... B-32
B.4.2.7.10 Use Case 6 ..... B-32
B.4.2.7.11 Use Case 7 (C1-S1-Uc7) – Landing/Post-Flight B-32
B.4.3 Conops 2 Local Area Operations B-33
B.4.3.1 Media And Incident Reporting Scenario (C2-S1) B-33
B.4.3.1.1 Overview B-33
B.4.3.1.2 Additional Assumptions B-33
B.4.3.1.3 Flight Profile B-34
B.4.3.1.4 Scenario Description B-34
B.4.3.1.5 Use Cases B-35
B.4.3.1.6 Use Case Descriptions B-35
B.4.3.1.6.1 Use Case 0. (C2-S1-Uc0.) Continuous Monitoring And Parameter Changes B-35
B.4.3.1.6.2 Use Case 0.1 (C2-S1-Uc0.1) Continuous Monitoring B-35
B.4.3.1.6.3 Use Case 0.2 (C2-S1-Uc0.2) Parameter Change Within The Air/Ground Portion Of The C2 Link System B-36
B.4.3.1.6.4 Use Case 0.3 (C2-S1-Uc0.3) Parameter Change Within The Ground/Ground Portion Of The C2csp's System B-36
B.4.3.1.6.5 Use Case 1 (C2-S1-Uc1) - Pre-Flight/Takeoff B-36
B.4.3.1.6.6 Use Case 2 (C2-S1-Uc2) - Departure B-36
B.4.3.1.6.7 Use Case 3 (C2-S1-Uc3) – Terrestrial → Terrestrial B-37
B.4.3.1.6.8 Use Case 4 (C2-S1-Uc4) – Reroute B-37
B.4.3.1.6.9 Use Case 5 (C2-S1-Uc5) – Arrival B-37
B.4.3.1.6.10 Use Case 6 (C2-S1-Uc6) - Terrestrial → Terrestrial B-37
B.4.3.1.6.11 Use Case 7 (C2-S1-Uc7) – Landing/Post-Flight B-37
B.4.3.1.7 Use Case 8 (C2-S1-Uc-8 Post-Flight) B-38
B.4.3.2 Local Cargo Delivery (C2-S2) B-38
B.4.3.2.1 Overview B-38
B.4.3.2.2 Additional Assumptions For Local Cargo Delivery Aircraft (LCDA) B-38
B.4.3.2.2.1 Technical Assumptions B-38
B.4.3.2.2.2 Other Assumptions B-38
B.4.3.2.3 Scenario Description B-39
B.4.3.2.4 Flight Profile B-40
B.4.3.2.5 Use Cases B-40
B.4.3.2.6 Use Case Descriptions B-40
B.4.3.3 Local Area Operations - Air Taxi (C2-S3) B-45
B.4.3.3.1 Introduction B-45
B.4.3.3.1.1 Definitions B-47
B.4.3.3.2 Air Taxi Operations With Remote Pilot Operating With ATC Clearance Under Instrument Flight Rules (C2-S3b) Or Within Designated UAM Corridors (C2-S3c) .. B-48
B.4.3.3.2.1 Scenario Overview B-48
B.4.3.3.2.2 Assumptions B-48
B.4.3.3.2.3 Flight Profile B-50
B.4.3.3.2.4 Use Case Overview B-53
B.4.3.3.2.5 Scenario Description B-53
B.4.3.3.2.6 Use Cases B-54
B.4.4 Conops 3 Extended Aerial Operations B-61
B.4.4.1 Surface Operations B-61
B.4.4.1.1 Overview B-61
B.4.4.1.1.1 Basline Scenario Overview B-62
B.4.4.1.1.2 Advanced Scenario Overview B-62
B.4.4.1.2 Taxi Information Exchange Categories B-62
B.4.4.1.3 Assumptions B-64
B.4.4.1.4 Ground Movement Profile B-72
B.4.4.1.5 Scenario Description B-74

B.4.4.1.6 Use Cases B-75
B.4.4.2 Remote Area Operations Scenario - Alaska Pipeline Inspection (C3-S1) B-83
B.4.4.2.1 Overview B-83
B.4.4.2.2 Additional Assumptions B-83
B.4.4.2.3 Flight Profile B-83
B.4.4.2.4 Scenario Description B-84
B.4.4.2.5 Use Cases B-84
B.4.4.2.6 Use Case Descriptions B-85
B.4.4.3 Maritime Surveillance Scenario (C3-S2) B-90
B.4.4.3.1 Overview B-90
B.4.4.3.2 Additional Assumptions B-90
B.4.4.3.3 Flight Profile B-91
B.4.4.3.4 Scenario Description B-91
B.4.4.3.5 Use Cases B-92
B.4.4.3.6 Use Case Descriptions B-92
B.4.4.4 Coast-To-Coast Aerial Work Surveys Scenario B-96
B.4.4.4.1 Overview B-96
B.4.4.4.2 Additional Assumptions B-97
B.4.4.4.3 Flight Profile B-97
B.4.4.4.4 Scenario Description B-98
B.4.4.4.5 Use Cases B-98
B.4.4.4.6 Use Case Descriptions B-99
B.4.4.5 Containment Volume Aerial Work Scenario (C3-S4) B-105
B.4.4.6 Regional Cargo Delivery (C3-S5) B-105
B.4.4.6.1 Overview B-105
B.4.4.6.2 Additional Assumptions. B-105
B.4.4.6.2.1 Technical Assumptions B-106
B.4.4.6.3 Other Assumptions B-106
B.4.4.6.4 Flight Profile B-106
B.4.4.6.5 Scenario Description B-106
B.4.4.6.6 Use Cases B-107
B.4.4.6.7 Use Case Descriptions B-108
B.4.5 Conops 4 High Altitude Long Endurance (HALE) Operations B-111
B.4.5.1 High Altitude Platform System (HAPS) (C4-S1) B-111
B.4.5.1.1 Overview B-111
B.4.5.1.2 Additional Assumptions B-112
B.4.5.1.3 Flight Profile B-112
B.4.5.1.4 Scenario Description B-113
B.4.5.1.5 Use Cases B-114
B.4.5.2 Use Case Descriptions B-114
B.4.5.3 Scenario High Altitude Relay System Scenario (C4-S2) B-118
B.4.5.3.1 Additional Assumptions B-118
B.4.5.3.2 Flight Profile B-118
B.4.5.3.3 Scenario Description B-119
B.4.5.3.4 Use Cases B-120
B.4.5.4 Recovery/Post-Flight (Local Terrestrial C2 Link System) Use Case Descriptions B-121
B.4.6 Conops 5 Low Altitude Delivery Supporting Small Package Delivery Operations B-124
B.4.6.1 Small Package Delivery Using Advanced Technologies (C5-S1) B-125
B.4.6.1.1 Assumptions B-125
B.4.6.1.3 Use Cases B-128
B.5 THE SE PROCESS OPERATIONAL AND SYSTEM VIEWS B-132
B.5.1 Operational View Of C2 Link System (OV-1) B-133
B.5.1.1 Overview Of A Representative Scenario B-133
B.5.1.2 Use Cases Potentially Stressing The Effectiveness Of The C2 Link System B-134

B.5.2 Configuration Options For The C2 Link System (SV-1) B-135
B.5.2.1 Possible Configurations Of C2 Link Systems B-135
B.5.2.2 C2 Link System Switchovers B-137
B.5.2.3 C2 Link System Control Station Handovers B-137
B.5.3 C2 Link System Architectural View (Sv-3) B-137
B.5.3.1 Types Of Air/Ground Links B-138
B.5.3.1.1 Terrestrial-Based Air/Ground Links B-138
B.5.3.1.2 High Altitude Relay Air/Ground Links B-139
B.5.3.1.3 Satellite Air/Ground Links B-139
B.5.3.2 Types Of Ground/Ground Links B-141
B.5.3.3 Link System Implementation Responsibilities B-141
B.5.4 Needed Information Exchanges - Ov-2 Operational Resource Flow Description/Node Connectivity Description B-142
B.5.5 Operational Activity Identification – Ov-5 ..... B-144
B.5.6 C2 Link System Functionality Description (Ov-4) B-145
B.5.7 Key Subsystems Of The C2 Link System And Those To Which It Connects (SV-2) B-146
B.5.8 The Information Exchanges Supporting All The Scenarios In Appendix B.4 (OV-3) B-150
B.5.8.1 Operations And Activities Performed In Each Phases Of Flight B-151
B.5.8.1.1 Pre-Flight Planning B-152
B.5.8.1.2 Start/Ground Movement/Taxi Phase B-152
B.5.8.1.3 Takeoff/Departure Phase B-152
B.5.8.1.4 Cruise Phase B-153
B.5.8.1.5 Aerial Work Phase B-153
B.5.8.1.6 Descent/Final Approach/Landing Phase B-153
B.5.8.1.7 Post Landing (Ground Movement/Taxi/Shutdown) Phase B-154
B.5.8.2 Airspace Class And Phase Of Flight Simplification B-154
B.5.8.3 Airspace Class, Operational Environment, Types Of Loss Of C2 Link System Functionality Addressed In IN OV-3 ..... B-155
B.6 RESULTING OPERATIONAL AND FUNCTIONAL REQUIREMENTS B-159
B.6.1 Operational Requirements (OR) B-159
B.6.2 Functional Requirements (FR) B-161
B.7 REFERENCES B-162

APPENDIX C OPERATIONAL SAFETY ASSESSMENT C-1

C.1 INTRODUCTION C-1
C.2 SCOPE C-3
C.2.1 Automatic Takeoff And Landing System Assumptions (ATOL) C-16
C.3 SAFETY RISK MANAGEMENT PANEL C-18
C.4 RISK ASSESSMENT C-19
C.4.1 Analysis Method C-19
C.4.2 Risk Determination C-31
C.4.3 Identification Of Mitigations C-38
C.4.4 Description Of The Hazards C-41
C.4.4.1 Hazard Results Based On Causes For Conventional Scenarios (Other Than Small Package Delivery And Air Taxi) C-45
C.4.4.1.1 Hazards For Conventional Scenarios Caused By Corrupted C2 Link (FR-1) C-46
C.4.4.1.1.1 Corrupted C2 Link For Aviate Activity (FR-1.1) For Conventional Scenarios - UA Executes Unexpected Action C-47
C.4.4.1.1.2 Corrupted C2 Link For Conventional Scenarios Communicate Activity (FR-1.2) C-53
C.4.4.1.1.3 Corrupted C2 Link For Conventional Scenarios Navigate Activity (FR-1.3) - Corrupted Data Causes The UA To Deviate From Its Intended Course Or Flight Plan C-53

C.4.4.1.1.4 Corrupted C2 Link For Conventional Scenarios Integrate Activity (FR-1.4) – Remote Pilot Receives Incorrect Information/Alert. Incorrect Information Is Received At The CS C-60
C.4.4.1.2 Hazard Results Based On Interrupted C2 Link For Conventional Scenarios C-65
C.4.4.1.2.1 Interrupted C2 Link For Conventional Scenarios Aviate Activity (FR-1.1) - Inadequate Or Lack Of Maneuver When One Is Required C-66
C.4.4.1.2.2 Interrupted C2 Link For Conventional Scenarios Communicate Activity (FR-1.2)- Remote Pilot Does Not Receive ATC Instruction C-80
C.4.4.1.2.3 Interrupted C2 Link For Conventional Scenarios Navigate Activity (FR-1.3) - Inadequate Or Lack Of Maneuver When One Is Required Or UA Deviates From Intended Course . C-87
C.4.4.1.2.4 Interrupted C2 Link For Conventional Scenarios Integrate Activity (FR-1.4) – Remote Pilot Does Not Receive Alert In A Timely Manner C-96
C.4.4.2 Hazard Results Based On C2 Link System Causes For Air Taxi Operations C-105
C.4.4.2.1.1 Corrupted C2 Link For Air Taxi Aviate Activity (FR-1.1)- UA Executes Unexpected Action C-106
C.4.4.2.1.2 Corrupted C2 Link For Air Taxi Communicate Activity (FR-1.2) - Corrupted Communications Results In Remote Pilot Not Receiving ATC Instructions C-111
C.4.4.2.1.3 Corrupted C2 Link For Air Taxi Navigate Activity (FR-1.3) – UA Deviates From Intended Flight Plan. C-113
C.4.4.2.1.4 Corrupted C2 Link For Air Taxi Integrate Activity (FR 1.4) – Remote Pilot Receives Incorrect Information/Alerts C-118
C.4.4.2.2.1 Interrupted C2 Link For Air Taxi Aviate Activity (FR-1.1) - Inadequate Or Lack Of Maneuver When One Is Required C-120
C.4.4.2.2.2 Interrupted C2 Link For Air Taxi Communicate Activity (FR-1.2)- Remote Pilot Does Not Receive ATC Instruction C-124
C.4.4.2.2.3 Interrupted C2 Link For Air Taxi Navigate Activity (FR-1.3) - Inadequate Or Lack Of Maneuver When One Is Required Or UA Deviates From Intended Course C-133
C.4.4.2.2.4 Interrupted C2 Link For Integrate Activity (FR-1.4) – Remote Pilot Does Not Receive Alert In A Timely Manner C-138
C.4.4.3.1.1 Corrupted C2 Link For Small Package Delivery (SPD) In Aviate Activity (FR-1.1) - UA Executes Unexpected Action C-142
C.4.4.3.1.2 Corrupted C2 Link For Small Package Delivery (SPD) Communicate Activity (FR-1.2)- Remote Pilot Does Not Receive ATC Instruction C-144
C.4.4.3.1.3 Corrupted C2 Link For Small Package Delivery (SPD) In Navigate Activity (FR-1.3) - UA Deviates From Intended Flight Plan C-144
C.4.4.3.1.4 Corrupted C2 Link For Small Package Delivery (SPD) In Integrate Activity (FR-1.4) - UA Executes Unexpected Action C-147
C.4.4.3.2.1 Interrupted C2 Link For Spd Aviate Activity (FR-1.1) - Inadequate Or Lack Of Maneuver When One Is Required C-148
C.4.4.3.2.2 Interrupted C2 Link For Spd Communicate Activity (FR-1.2)- Remote Pilot Does Not Receive ATC Instruction C-150
C.4.4.3.2.3 Interrupted C2 Link For Small Package Delivery (SPD) In Navigate Activity (FR-1.3 - UA Executes Unexpected Action C-150
C.4.4.3.2.4 Interrupted C2 Link For Small Package Delivery (SPD) In Integrate Activity (FR-1.4) - UA Executes Unexpected Action C-153
C.4.4.4 Manage C2 Link Functional Requirement (FR-2) For Conventional Operations C-155
C.4.4.4.1.1 Corrupted C2 Link For Conventional Operations Manage C2 Link – Hazards Caused By Corrupted C2 Link Establish/Terminate (FR-2.1)– Misdirected C2 Link C-155
C.4.4.4.1.2 Corrupted C2 Link For Conventional Operations Manage C2 Link Manage C2 Link – Switchovers (FR-2.2)– Misdirected C2 Link C-156
C.4.4.4.1.3 Corrupted C2 Link For Conventional Operations Manage C2 Link Manage C2 Link – Handovers (FR-2.3)– Misdirected C2 Link C-156

C.4.4.4.2.1 Interrupted C2 Link For Conventional Operations Manage C2 Link – Establish/Terminate (FR-2.1) – Failed C2 Link C-159
C.4.4.4.2.2 Interrupted C2 Link For Conventional Operations Manage C2 Link – Failed Switchovers (FR-2.2) Failed C2 Link C-159
C.4.4.4.2.3 Interrupted C2 Link For Conventional Operations Manage C2 Link – Failed Handover (FR-2.3) – Failed C2 Link C-160
C.4.4.4.3.1 Corrupted C2 Link For Air Taxi Operations Manage C2 Link –Establish/Terminate (FR-2.1)– Misdirected C2 Link C-164
C.4.4.4.3.2 Corrupted C2 Link For Air Taxi Operations Manage C2 Link – (FR-2.2) – Misdirected C2 Link During Switchovers C-164
C.4.4.4.3.3 Corrupted C2 Link For Air Taxi Operations Manage C2 Link (FR-2.3)– Misdirected C2 Link During Handovers C-164
C.4.4.4.4 Interrupted C2 Link For Air Taxi – Manage C2 Link C-167
C.4.4.4.4.1 Interrupted C2 Link For Air Taxi -Manage C2 Link – Establish/Terminate (FR-2.1) – Failed C2 Link C-167
C.4.4.4.4.2 Interrupted C2 Link For Air Taxi- Manage C2 Link – Failed Switchovers (FR-2.2) Failed C2 Link C-167
C.4.4.4.4.3 Interrupted C2 Link For Air Taxi- Manage C2 Link - Failed Handover (FR-2.3) – Failed C2 Link C-167
C.4.4.4.5 Corrupted C2 Link For SPD Operations Manage C2 Link – Hazards Caused By Corrupted C2 Link Establish/Terminate (FR-2.1, FR-2.2 And FR-2.3)– Misdirected C2 Link C-169
C.4.4.4.5.1 Corrupted C2 Link For SPD Hazards Caused By Corrupted C2 Link Establish/Terminate (FR-2.1) C-169
C.4.4.4.5.2 Corrupted C2 Link For SPD Hazards Caused By Corrupted C2 Link Switchovers (FR-2.2) C-169
C.4.4.4.5.3 Corrupted C2 Link For SPD Hazards Caused By Corrupted C2 Link Handovers (FR-2.3) C-169
C.4.4.4.5.4 Interrupted C2 Link For SPD Operations Manage C2 Link – Hazards Caused By Failed C2 Link To Establish/Terminate (FR-2.1, FR-2.2 And FR-2.3)– Failed Switchovers Andhandovers C-171
C.4.4.4.5.5 Interrupted C2 Link For SPD Hazards Caused By Corrupted C2 Link Establish/ Terminate (FR-2.1) C-171
C.4.4.4.5.6 Interrupted C2 Link For Spd Hazards Caused By Failed C2 Link Switchovers (FR-2.3) For SPD C-171
C.4.4.4.5.7 Interrupted C2 Link For Spd Hazards Caused By Failed C2 Link Handovers (Fr-2.3) For Spd C-171
C.4.4.5.1 Manage C2 Link For Conventional; Air Taxi; And SPD Operations – Status Reports (FR-3.1) – Missing Or Erroneous Status Reports C-173
C.4.4.5.2 Change To C2 Link Systems Operating Parameter For Conventional And Air Taxi Operations– (FR-3.2 And FR-3.3) C-179
C.4.4.6 Summary Of Safety Requirements, Mitigations, And Recommendations C-182
C.4.5 Operational Hazards And Safety Objectives (Required Likelihoods) C-183
C.5 CURRENT REGULATIONS USED AS EXISTING CONTROLS C-247
C.5.1 Regulations C-247
C.5.2 See And Avoid C-259
C.5.3 DAA System Overview C-259
C.5.4 Top-Level Architecture For DAA C-259
C.5.5 DAA Well Clear Definition C-260
C.5.6 Flyaway C-261
C.5.7 Single Point Of Failure C-261
C.5.8 Recommendations C-261
C.5.9 Safety Risk Management Term Definitions C-263
C.6 REFERENCES C-264

APPENDIX D OPERATIONAL PERFORMANCE ASSESSMENT D-1

D.1 INTRODUCTION D-1
D.1.1 RLTP Availability D-3
D.1.2 RLTP Continuity D-4
D.1.3 RLTP Integrity D-4
D.1.4 RLTP Latency D-4
D.1.5 Per Flight Hour Considerations D-5
D.1.6 Overview Of OPA Methodology To Determine RLTP D-5
D.1.7 RLTP Requirements D-6
D.1.8 Organization Of The OPA Assessments D-6
D.1.9 Corrupted Cause D-12
D.1.9.1 Example Of A Corrupted Cause RLTP Assessment D-12
D.1.10 Interrupted Cause D-17
D.1.10.1 Example Of An Interrupted Cause RLTP Assessment D-17
D.1.11 Summary Of RLTP Assessments D-23
D.2 C2 LINK SYSTEM LATENCY D-23
D.2.1 C2 Link Latency For The Remote Pilot Aviate, Navigate And Integrate Activities D-23
D.2.1.1 Latency Assumptions D-24
D.2.1.2 Considerations Regarding The C2 Link System Latency Estimates D-28
D.2.2 C2 Link Latency For The Remote Pilot Communicate Activity D-28
D.2.2.1 Communicate Latency Considerations D-30
D.3 OPA ASSESSMENT FOR SURFACE TAXI OPERATIONS D-32
D.3.1 Non-Towered– Baseline Taxi D-32
D.3.1.1 Corrupted Cause D-32
D.3.1.1.1 RLTP Integrity For Aviate D-32
D.3.1.1.2 RLTP Integrity For Navigate D-32
D.3.1.1.3 RLTP Integrity For Integrate D-32
D.3.1.2 Interrupted Cause D-33
D.3.1.2.1 Transaction Timelines D-33
D.3.1.2.2 Transaction Expiration Time (TET) D-33
D.3.1.2.2.1 Stop For FOD D-33
D.3.1.2.2.2 Video Initiated Turn Not Executed By UA D-33
D.3.1.2.2.3 Video Initiated Stop Not Executed By UA D-34
D.3.1.2.3 RLTP Availability And Continuity For Aviate D-34
D.3.1.2.3.1 RLTP Availability For Aviate D-34
D.3.1.2.3.2 RLTP Continuity For Aviate D-35
D.3.1.2.4 RLTP Availability And Continuity For Navigate D-35
D.3.1.2.4.1 RLTP Availability For Navigate D-35
D.3.1.2.4.2 RLTP Continuity For Navigate D-35
D.3.1.2.5 RLTP Availability And Continuity For Integrate D-35
D.3.1.2.5.1 RLTP Availability For Integrate D-35
D.3.1.2.5.2 RLTP Continuity For Integrate D-35
D.3.2 Non-Towered – Advanced Taxi D-35
D.3.2.1 Corrupted Cause D-35
D.3.2.1.1 RLTP Integrity For Aviate D-36
D.3.2.1.2 RLTP Integrity For Navigate D-36
D.3.2.1.3 RLTP Integrity For Integrate D-36
D.3.2.2 Interrupted Cause D-36
D.3.2.2.1 Transaction Timelines D-36
D.3.2.2.2 TET D-36
D.3.2.2.2.1 Stop Now Not Executed By UA D-36
D.3.2.2.2.2 Remote Pilot Initiated Taxi Route Revision Not Executed By UA D-37
D.3.2.2.3 RLTP Availability And Continuity For Aviate D-37

D.3.2.2.3.1 RLTP Availability For Aviate D-38
D.3.2.2.3.2 RLTP Continuity For Aviate D-38
D.3.2.2.4 RLTP Availability And Continuity For Navigate D-38
D.3.2.2.4.1 RLTP Availability For Navigate D-38
D.3.2.2.4.2 RLTP Continuity For Navigate D-38
D.3.2.2.5 RLTP Availability And Continuity For Integrate D-38
D.3.2.2.5.1 RLTP Availability For Integrate D-38
D.3.2.2.5.2 RLTP Continuity For Integrate D-38
D.3.3 Towered – Baseline Taxi D-39
D.3.3.1 Corrupted Cause D-39
D.3.3.1.1 RLTP Integrity For Aviate D-39
D.3.3.1.2 RLTP Integrity For Navigate D-39
D.3.3.1.3 RLTP Integrity For Integrate D-39
D.3.3.2 Interrupted Cause D-39
D.3.3.2.1 Transaction Timelines D-40
D.3.3.2.2 TET D-40
D.3.3.2.2.1 Stop For FOD D-40
D.3.3.2.2.2 ATC Initiated Instruction/Clearance Not Acknowledged By Remote Pilot D-40
D.3.3.2.2.3 Video Initiated Turn Not Executed By UA D-40
D.3.3.2.2.4 Video Initiated Stop Not Executed By UA D-40
D.3.3.2.3 RLTP Availability And Continuity For Aviate D-40
D.3.3.2.3.1 RLTP Availability For Aviate D-40
D.3.3.2.3.2 RLTP Continuity For Aviate D-40
D.3.3.2.4 RLTP Availability And Continuity For Communicate D-41
D.3.3.2.4.1 RLTP Availability For Communicate D-41
D.3.3.2.4.2 RLTP Continuity For Communicate D-41
D.3.3.2.5 RLTP Availability And Continuity For Navigate D-41
D.3.3.2.5.1 RLTP Availability For Navigate D-41
D.3.3.2.5.2 RLTP Continuity For Navigate D-41
D.3.3.2.6 RLTP Availability And Continuity For Integrate D-41
D.3.3.2.6.1 RLTP Availability For Integrate D-41
D.3.3.2.6.2 RLTP Continuity For Integrate D-41
D.3.4 Towered – Advanced Taxi D-42
D.3.4.1 Corrupted Cause D-42
D.3.4.1.1 RLTP Integrity For Aviate D-42
D.3.4.1.2 RLTP Integrity For Navigate D-42
D.3.4.1.3 RLTP Integrity For Integrate D-42
D.3.4.2 Interrupted Cause D-42
D.3.4.2.1 Transaction Timelines D-42
D.3.4.2.2 TET D-42
D.3.4.2.2.1 Stop Now Not Executed By UA D-42
D.3.4.2.2.2 ATC Initiated Instruction/Clearance Not Acknowledged By Remote Pilot D-43
D.3.4.2.2.3 Remote Pilot Initiated Taxi Route Revision Not Executed By UA D-43
D.3.4.2.3 RLTP Availability And Continuity For Aviate D-43
D.3.4.2.3.1 RLTP Availability For Aviate D-43
D.3.4.2.3.2 RLTP Continuity For Aviate D-43
D.3.4.2.4 RLTP Availability And Continuity For Communicate D-43
D.3.4.2.4.1 RLTP Availability For Communicate D-43
D.3.4.2.4.2 RLTP Continuity For Communicate D-43
D.3.4.2.5 RLTP Availability And Continuity For Navigate D-43
D.3.4.2.5.1 RLTP Availability For Navigate D-44
D.3.4.2.5.2 RLTP Continuity For Navigate D-44
D.3.4.2.6 RLTP Availability And Continuity For Integrate D-44
D.3.4.2.6.1 RLTP Availability For Integrate D-44

D.3.4.2.6.2 RLTP Continuity For Integrate D-44
D.4 OPA ASSESSMENT FOR SURFACE TAKEOFF AND LANDING OPERATIONS D-44
D.4.1 Non-Towered-Baseline D-44
D.4.1.1 Corrupted Cause D-44
D.4.1.1.1 RLTP Integrity For Aviate D-45
D.4.1.1.2 RLTP Integrity For Navigate D-45
D.4.1.1.3 RLTP Integrity For Integrate D-45
D.4.1.2 Interrupted Cause D-45
D.4.1.2.1 Transaction Timelines D-45
D.4.1.2.2 TET D-45
D.4.1.2.3 Remote Pilot Initiated Approach Not Executed By UA D-45
D.4.1.2.4 Remote Pilot Initiated Abort Takeoff Not Executed By UA D-46
D.4.1.2.5 RLTP Availabilty And Continuity For Aviate D-47
D.4.1.2.5.1 RLTP Availability For Aviate D-47
D.4.1.2.5.2 RLTP Continuity For Aviate D-47
D.4.1.2.6 RLTP Availability And Continuity For Navigate D-47
D.4.1.2.6.1 RLTP Availability For Navigate D-47
D.4.1.2.6.2 RLTP Continuity For Navigate D-47
D.4.1.2.7 RLTP Availability And Continuity For Integrate D-47
D.4.1.2.7.1 RLTP Availability For Integrate D-48
D.4.1.2.7.2 RLTP Continuity For Integrate D-48
D.4.2 Non-Towered -Advanced D-48
D.4.2.1 Corrupted Cause D-48
D.4.2.1.1 RLTP Integrity For Navigate D-48
D.4.2.1.2 RLTP Integrity For Integrate D-48
D.4.2.2 Interrupted Cause D-48
D.4.2.2.1 Transaction Timelines D-48
D.4.2.2.2 TET D-49
D.4.2.2.3 Remote Pilot Initiated Approach Not Executed By UA D-49
D.4.2.2.4 UA Initiated Abort Takeoff Not Executed By UA D-49
D.4.2.2.5 RLTP Availability And Continuity For Aviate D-49
D.4.2.2.5.1 RLTP Availability For Aviate D-49
D.4.2.2.5.2 RLTP Continuity For Aviate D-49
D.4.2.2.6 RLTP Availability And Continuity For Integrate D-49
D.4.2.2.6.1 RLTP Availability For Integrate D-50
D.4.2.2.6.2 RLTP Continuity For Integrate D-50
D.4.3 Towered - Baseline D-50
D.4.3.1 Corrupted Cause D-50
D.4.3.1.1 RLTP Integrity For Aviate D-50
D.4.3.1.2 RLTP Integrity For Navigate D-50
D.4.3.1.3 RLTP Integrity For Integrate D-50
D.4.3.2 Interrupted Cause D-50
D.4.3.2.1 Transaction Timelines D-51
D.4.3.2.2 TET D-51
D.4.3.2.3 ATC Initiated Takeoff Not Executed By UA D-51
D.4.3.2.4 ATC Initiated Abort Takeoff Not Executed By UA D-51
D.4.3.2.5 RLTP Availability And Continuity For Aviate D-51
D.4.3.2.5.1 RLTP Availability For Aviate D-52
D.4.3.2.5.2 RLTP Continuity For Aviate D-52
D.4.3.2.6 RLTP Availability And Continuity For Communicate D-52
D.4.3.2.6.1 RLTP Availability For Communicate D-52
D.4.3.2.6.2 RLTP Continuity For Communicate D-52
D.4.3.2.7 RLTP Availability And Continuity For Navigate D-52

D.4.3.2.7.1 RLTP Availability For Navigate D-52
D.4.3.2.7.2 RLTP Continuity For Navigate D-52
D.4.3.2.8 RLTP Availability And Continuity For Integrate D-53
D.4.3.2.8.1 RLTP Availability For Integrate D-53
D.4.3.2.8.2 RLTP Continuity For Integrate D-53
D.4.4 Towered - Advanced D-53
D.4.4.1 Corrupted Cause D-53
D.4.4.1.1 RLTP Integrity For Navigate D-53
D.4.4.1.2 RLTP Integrity For Integrate D-53
D.4.4.2 Interrupted Cause D-53
D.4.4.2.1 Transaction Timelines D-54
D.4.4.2.2 TET D-54
D.4.4.2.3 ATC Initiated Takeoff Not Executed By UA D-54
D.4.4.2.4 ATC Initiated Abort Takeoff Not Executed By UA D-54
D.4.4.2.5 RLTP Availability And Continuity For Aviate D-54
D.4.4.2.5.1 RLTP Availability For Aviate D-54
D.4.4.2.5.2 RLTP Continuity For Aviate D-54
D.4.4.2.6 RLTP Availability And Continuity For Communicate D-55
D.4.4.2.6.1 RLTP Availability For Communicate D-55
D.4.4.2.6.2 RLTP Continuity For Communicate D-55
D.4.4.2.7 RLTP Availability And Continuity For Navigate D-55
D.4.4.2.7.1 RLTP Availability For Navigate D-55
D.4.4.2.7.2 RLTP Continuity For Navigate D-55
D.4.4.2.8 RLTP Availability And Continuity For Integrate D-55
D.4.4.2.8.1 RLTP Availability For Integrate D-55
D.4.4.2.8.2 RLTP Continuity For Integrate D-56
D.5 OPA ASSESSMENT FOR DEPARTURE AND ARRIVAL OPERATIONS D-56
D.5.1 Non-Towered D-56
D.5.1.1 Corrupted Cause D-56
D.5.1.1.1 RLTP Integrity For Aviate D-56
D.5.1.1.2 RLTP Integrity For Navigate D-56
D.5.1.1.3 RLTP Integrity For Integrate D-56
D.5.1.2 Interrupted Cause D-56
D.5.1.2.1 Transaction Timelines D-57
D.5.1.2.2 TET D-57
D.5.1.2.2.1 ATC Initiated Approach Not Executed By Remote Pilot/UA D-57
D.5.1.2.2.2 Remote Pilot Initiated Missed Approach/Go Around Not Executed By UA D-57
D.5.1.2.2.3 DAA Initiated Maneuver For Separation Not Executed By Remote Pilot/UA D-58
D.5.1.2.3 RLTP Availability And Continuity For Aviate D-58
D.5.1.2.3.1 RLTP Availability For Aviate D-58
D.5.1.2.3.2 RLTP Continuity For Aviate D-58
D.5.1.2.4 RLTP Availability And Continuity For Communicate D-58
D.5.1.2.4.1 RLTP Availability For Communicate D-59
D.5.1.2.4.2 RLTP Continuity For Communicate D-59
D.5.1.2.5 RLTP Availability And Continuity For Navigate D-59
D.5.1.2.5.1 RLTP Availability For Navigate D-59
D.5.1.2.5.2 RLTP Continuity For Navigate D-59
D.5.1.2.6 RLTP Availability And Continuity For Integrate D-59
D.5.1.2.6.1 RLTP Availability For Integrate D-59
D.5.1.2.6.2 RLTP Continuity For Integrate D-59
D.5.2 Towered D-60
D.5.2.1 Corrupted Cause D-60
D.5.2.1.1 RLTP Integrity For Aviate D-60
D.5.2.1.2 RLTP Integrity For Navigate D-60

D.5.2.1.3 RLTP Integrity For Integrate D-60
D.5.2.2 Interrupted Cause D-60
D.5.2.2.1 Transaction Timelines D-60
D.5.2.2.2 TET D-61
D.5.2.2.2.1 ATC Initiated Approach Not Executed By Remote Pilot/UA D-61
D.5.2.2.2.2 ATC Initiated Missed Approach/Go Around Not Executed By Remote Pilot/UA D-62
D.5.2.2.2.3 DAA Initiated Maneuver For Separation Not Executed By Remote Pilot/UA D-63
D.5.2.2.3 RLTP Availability And Continuity For Aviate D-63
D.5.2.2.3.1 RLTP Availability For Aviate D-63
D.5.2.2.3.2 RLTP Continuity For Aviate D-63
D.5.2.2.4 RLTP Availability And Continuity For Communicate D-63
D.5.2.2.4.1 RLTP Availability For Communicate D-63
D.5.2.2.4.2 RLTP Continuity For Communicate D-64
D.5.2.2.5 RLTP Availability And Continuity For Navigate D-64
D.5.2.2.5.1 RLTP Availability For Navigate D-64
D.5.2.2.5.2 RLTP Continuity For Navigate D-64
D.5.2.2.6 RLTP Availability And Continuity For Integrate D-64
D.5.2.2.6.1 RLTP Availability For Integrate D-64
D.5.2.2.6.2 RLTP Continuity For Integrate D-64
D.6 OPA ASSESSMENT FOR TRANSIT/EXTENDED OPERATIONS D-64
D.6.1 Class A Airspace D-64
D.6.1.1 Corrupted Cause D-64
D.6.1.1.1 RLTP Integrity For Aviate D-65
D.6.1.1.2 RLTP Integrity For Navigate D-65
D.6.1.2 Interrupted Cause D-65
D.6.1.2.1 Transaction Timelines D-65
D.6.1.2.2 TET D-66
D.6.1.2.2.1 ATC Initiated Maneuver For Separation Not Executed By Remote Pilot/UA D-66
D.6.1.2.2.2 Remote Pilot Initiated Maneuver Not Executed By Remote Pilot/UA In FMS Mode D-66
D.6.1.2.3 RLTP Availability And Continuity For Aviate D-66
D.6.1.2.3.1 RLTP Availability For Aviate D-66
D.6.1.2.3.2 RLTP Continuity For Aviate D-66
D.6.1.2.4 RLTP Availability And Continuity For Communicate D-66
D.6.1.2.4.1 RLTP Availability For Communicate D-67
D.6.1.2.4.2 RLTP Continuity For Communicate D-67
D.6.1.2.5 RLTP Availability And Continuity For Navigate D-67
D.6.1.2.5.1 RLTP Availability For Navigate D-67
D.6.1.2.5.2 RLTP Continuity For Navigate D-67
D.6.2 Class B, C, And E Airspace D-67
D.6.2.1 Corrupted Cause D-67
D.6.2.1.1 RLTP Integrity For Aviate D-68
D.6.2.1.2 RLTP Integrity For Navigate D-68
D.6.2.1.3 RLTP Integrity For Integrate D-68
D.6.2.2 Interrupted Cause D-68
D.6.2.2.1 Transaction Timelines D-68
D.6.2.2.2 TET D-68
D.6.2.2.2.1 ATC Initiated Maneuver For Separation Not Executed By Remote Pilot/UA D-68
D.6.2.2.2.2 DAA Initiated Maneuver For Separation Not Executed By Remote Pilot/UA D-69
D.6.2.2.2.3 Remote Pilot Initiated Maneuver Not Executed By Remote Pilot/UA In FMS Mode D-70
D.6.2.2.3 RLTP Availability And Continuity For Aviate D-70
D.6.2.2.3.1 RLTP Availability For Aviate D-70
D.6.2.2.3.2 RLTP Continuity For Aviate D-70
D.6.2.2.4 RLTP Availability And Continuity For Communicate D-70
D.6.2.2.4.1 RLTP Availability For Communicate D-70

D.6.2.2.4.2 RLTP Continuity For Communicate D-70
D.6.2.2.5 RLTP Availability And Continuity For Navigate D-70
D.6.2.2.5.1 RLTP Availability For Navigate D-71
D.6.2.2.5.2 RLTP Continuity For Navigate D-71
D.6.2.2.6 RLTP Availability And Continuity For Integrate D-71
D.6.2.2.6.1 RLTP Availability For Integrate D-71
D.6.2.2.6.2 RLTP Continuity For Integrate D-71
D.6.3 Class G Airspace D-71
D.6.3.1 Corrupted Cause D-71
D.6.3.1.1 RLTP Integrity For Aviate D-72
D.6.3.1.2 RLTP Integrity For Navigate D-72
D.6.3.1.3 RLTP Integrity For Integrate D-72
D.6.3.2 Interrupted Cause D-72
D.6.3.2.1 Transaction Timelines D-72
D.6.3.2.2 TET D-72
D.6.3.2.2.1 DAA Initiated Maneuver For Separation Not Executed By Remote Pilot/UA D-72
D.6.3.2.2.2 Remote Pilot Initiated Maneuver Not Executed By Remote Pilot/UA In FGS Mode .. D-73
D.6.3.2.2.3 Remote Pilot Initiated Maneuver Not Executed By Remote Pilot/UA In FMS Mode . D-73
D.6.3.2.3 RLTP Availability And Continuity For Aviate D-73
D.6.3.2.3.1 RLTP Availability For Aviate D-73
D.6.3.2.3.2 RLTP Continuity For Aviate D-73
D.6.3.2.4 RLTP Availability And Continuity For Navigate D-73
D.6.3.2.4.1 RLTP Availability For Navigate D-73
D.6.3.2.4.2 RLTP Continuity For Navigate D-74
D.6.3.2.5 RLTP Availability And Continuity For Integrate D-74
D.6.3.2.5.1 RLTP Availability For Integrate D-74
D.6.3.2.5.2 RLTP Continuity For Integrate D-74
D.6.4 Oceanic A Airspace D-74
D.6.4.1 Corrupted Cause D-74
D.6.4.1.1 RLTP Integrity For Aviate D-75
D.6.4.1.2 RLTP Integrity For Navigate D-75
D.6.4.2 Interrupted Cause D-75
D.6.4.2.1 Transaction Timelines D-75
D.6.4.2.2 TET D-75
D.6.4.2.2.1 Remote Pilot Initiated Maneuver Not Executed By UA In FGS Mode D-75
D.6.4.2.2.2 Remote Pilot Initiated Maneuver Not Executed By UA In FMS Mode D-76
D.6.4.2.3 RLTP Availability And Continuity For Aviate D-76
D.6.4.2.3.1 RLTP Availability For Aviate D-76
D.6.4.2.3.2 RLTP Continuity For Aviate D-76
D.6.4.2.4 RLTP Availability And Continuity For Navigate D-76
D.6.4.2.4.1 RLTP Availability For Navigate D-76
D.6.4.2.4.2 RLTP Continuity For Navigate D-77
D.7 OPA FOR THE REMOTE PILOT'S MANAGE C2 LINK SYSTEM ACTIVITY D-77
D.7.1 Establish/Terminate D-77
D.7.2 Switchover D-81
D.7.2.1 Failed Switchovers D-81
D.7.2.1.1 Allowable Quantitative Probability D-81
D.7.2.1.2 Switchover Transaction Timeline And TET D-82
D.7.2.1.2.1 Scheduled Make Before Break Switchover D-82
D.7.2.1.2.2 Scheduled Break Before Make Switchover D-82
D.7.2.1.2.3 Unscheduled Make Before Break Switchover D-82
D.7.2.1.2.4 Unscheduled Break Before Make Switchover D-82
D.7.2.2 Misdirected Switchover D-83

D.7.2.3 Considerations On The C2 Link System's Support Of The Switchover Aspects Of The Support Of The Remote Pilot's Manage C2 Link System Activity D-83
D.7.3 Handover D-84
D.7.3.1 Failed Handovers D-84
D.7.3.1.1 Allowable Quantitative Probability D-84
D.7.3.1.2 Handover Transaction Timeline And TET D-84
D.7.3.1.2.1 Scheduled Make Before Break Handover D-84
D.7.3.1.2.2 Unscheduled Make Before Break Handover D-85
D.7.3.2 Misdirected Handover D-85
D.7.4 Status Reporting D-85
D.7.4.1 Latency Of The C2 Link System Status Reporting D-86
D.7.4.2 Missing C2 Link System Status Reports D-87
D.7.4.3 Erroneous C2 Link System Status Reporting D-87
D.7.4.4 Considerations On The C2 Link System's Status Reporting Aspects Of The Support Of The Remote Pilots Manage C2 Link System Activity D-88
D.7.5 External Changes To Operating Parameters D-88
D.7.5.1 Failed Change To Operating Parameters D-89
D.7.5.1.1 Allowable Quantitative Probability D-89
D.7.5.1.2 Change To Operating Parameters Timeline And TET D-89
D.7.5.2 Erroneous Operating Parameter Change D-90
D.8 SUMMARY OF CONVENTIONAL UAS RESULTS OF THE ASSESSMENTS D-90
D.8.1.1 Transaction Expiration Times D-90
D.8.2 Summary Of The C2 Link System's Performance When Supporting The Remote Pilot's Aviate, Communicate, Navigate And Integrate Activities D-96
D.8.3 Summary Of The C2 Link System's Performance When Supporting The Remote Pilot's Manage C2 Link System Activity D-96
D.9 OPA ASSESSMENT FOR AIR TAXI UAS SURFACE TAKEOFF AND LANDING OPERATIONS D-99
D.9.1 Non-Towered D-99
D.9.1.1 Corrupted Cause D-99
D.9.1.1.1 RLTP Integrity For Aviate D-99
D.9.1.1.2 RLTP Integrity For Navigate D-99
D.9.1.2 Interrupted Cause D-99
D.9.2 Towered D-99
D.9.2.1 Corrupted Cause D-99
D.9.2.1.1 RLTP Integrity For Aviate D-100
D.9.2.1.2 RLTP Integrity For Navigate D-100
D.9.2.2 Interrupted Cause D-100
D.10 OPA ASSESSMENT FOR AIR TAXI UAS DEPARTURE AND ARRIVAL OPERATIONS D-100
D.10.1 Non-Towered D-100
D.10.1.1 Corrupted Cause D-100
D.10.1.1.1.1 RLTP Integrity For Aviate D-101
D.10.1.1.1.2 RLTP Integrity For Navigate D-101
D.10.1.1.1.3 RLTP Integrity For Integrate D-101
D.10.1.2 Interrupted Cause D-101
D.10.1.2.1 Transaction Timelines D-101
D.10.1.2.2 TET D-101
D.10.1.2.2.1 ATC Initiated Approach Not Executed By Remote Pilot/UA D-101
D.10.1.2.2.2 Remote Pilot Initiated Missed Approach/Go Around Not Executed By UA D-101
D.10.1.2.2.3 DAA Initiated Warning Alert For Separation Not Executed By Remote Pilot/UA D-102
D.10.1.2.3 RLTP Availability And Continuity For Aviate D-102
D.10.1.2.3.1 RLTP Availability For Aviate D-102
D.10.1.2.3.2 RLTP Continuity For Aviate D-102

D.10.1.2.4 RLTP Availability And Continuity For Communicate D-102
D.10.1.2.4.1 RLTP Availability For Communicate D-103
D.10.1.2.4.2 RLTP Continuity For Communicate D-103
D.10.1.2.5 RLTP Availability And Continuity For Navigate D-103
D.10.1.2.5.1 RLTP Availability For Navigate D-103
D.10.1.2.5.2 RLTP Continuity For Navigate D-103
D.10.1.2.6 RLTP Availability And Continuity For Integrate D-103
D.10.1.2.7 RLTP Availability For Integrate D-103
D.10.1.2.7.1 RLTP Continuity For Integrate D-103
D.10.2 Towered D-104
D.10.2.1 Corrupted Cause D-104
D.10.2.1.1 RLTP Integrity For Aviate D-104
D.10.2.1.2 RLTP Integrity For Navigate D-104
D.10.2.1.3 RLTP Integrity For Integrate D-104
D.10.2.2 Interrupted Cause D-104
D.10.2.2.1 Transaction Timelines D-105
D.10.2.2.2 TET D-105
D.10.2.2.2.1 ATC Initiated Approach Not Executed By Remote Pilot/UA D-105
D.10.2.2.2.2 Remote Pilot Initiated Missed Approach/Go Around Not Executed By UA D-105
D.10.2.2.2.3 DAA Initiated Warning Alert For Separation Not Executed By Remote Pilot/UA D-105
D.10.2.2.2.4 RLTP Availability And Continuity For Aviate D-106
D.10.2.2.2.5 RLTP Availability For Aviate D-106
D.10.2.2.2.6 RLTP Continuity For Aviate D-106
D.10.2.2.2.7 RLTP Availability And Continuity For Communicate D-106
D.10.2.2.2.8 RLTP Availability For Communicate D-106
D.10.2.2.2.9 RLTP Continuity For Communicate D-106
D.10.2.2.2.10 RLTP Availability And Continuity For Navigate D-107
D.10.2.2.2.11 RLTP Availability For Navigate D-107
D.10.2.2.2.12 RLTP Continuity For Navigate D-107
D.10.2.2.2.13 RLTP Availability And Continuity For Integrate D-107
D.10.2.2.2.14 RLTP Availability For Integrate D-107
D.10.2.2.2.15 RLTP Continuity For Integrate D-107
D.11 OPA ASSESSMENT FOR AIR TAXI TRANSIT/EXTENDED OPERATIONS D-107
D.11.1 Class B, C, And E Airspace D-107
D.11.1.1 Corrupted Cause D-107
D.11.1.1.1 RLTP Integrity For Aviate D-108
D.11.1.1.2 RLTP Integrity For Communicate D-108
D.11.1.1.3 RLTP Integrity For Navigate D-108
D.11.1.1.4 RLTP Integrity For Integrate D-108
D.11.1.2 Interrupted Cause D-108
D.11.1.2.1 Transaction Timelines D-108
D.11.1.2.2 TET D-108
D.11.1.2.2.1 ATC Initiated Maneuver For Separation Not Executed By Remote Pilot/UA D-108
D.11.1.2.2.2 DAA Initiated Warning Alert For Separation Not Executed By Remote Pilot/UA D-109
D.11.1.2.2.3 Remote Pilot Initiated Maneuver Not Executed By UA In FMS Mode D-109
D.11.1.2.2.4 Remote Pilot Notification From Passenger Not Received By Remote Pilot D-110
D.11.1.2.2.5 RLTP Availability And Continuity For Aviate D-110
D.11.1.2.2.6 RLTP Availability For Aviate D-110
D.11.1.2.2.7 RLTP Continuity For Aviate D-110
D.11.1.2.2.8 RLTP Availability And Continuity For Communicate D-110
D.11.1.2.2.9 RLTP Availability For Communicate D-110
D.11.1.2.2.10 RLTP Continuity For Communicate D-110
D.11.1.2.2.11 RLTP Availability And Continuity For Navigate D-111
D.11.1.2.2.12 RLTP Availability For Navigate D-111

D.11.1.2.2.13 RLTP Continuity For Navigate D-111
D.11.1.2.2.14 RLTP Availability And Continuity For Integrate D-111
D.11.1.2.2.15 RLTP Availability For Integrate D-111
D.11.1.2.2.16 RLTP Continuity For Integrate D-111
D.11.2 UAM Corridor D-111
D.11.2.1 Corrupted Cause D-111
D.11.2.1.1 RLTP Integrity For Aviate D-112
D.11.2.1.2 RLTP Integrity For Communicate D-112
D.11.2.1.3 RLTP Integrity For Navigate D-112
D.11.2.1.4 RLTP Integrity For Integrate D-112
D.11.2.2 Interrupted Cause D-112
D.11.2.2.1 Transaction Timelines D-112
D.11.2.2.2 TET D-112
D.11.2.2.2.1 ATC Initiated Maneuver/Delay For Separation Not Executed By Remote Pilot/UA. D-112
D.11.2.2.2.2 DAA Initiated Warning Alert For Separation Not Executed By Remote Pilot/UA ... D-113
D.11.2.2.2.3 Remote Pilot Initiated Maneuver Not Executed By UA In FMS Mode D-113
D.11.2.2.2.4 Passenger Notification Not Received By Remote Pilot D-113
D.11.2.2.2.5 RLTP Availability And Continuity For Aviate D-113
D.11.2.2.2.6 RLTP Availability For Aviate D-114
D.11.2.2.2.7 RLTP Continuity For Aviate D-114
D.11.2.2.2.8 RLTP Availability And Continuity For Navigate D-114
D.11.2.2.2.9 RLTP Availability For Communicate D-114
D.11.2.2.2.10 RLTP Continuity For Communicate D-114
D.11.2.2.2.11 RLTP Availability For Navigate D-114
D.11.2.2.2.12 RLTP Continuity For Navigate D-114
D.11.2.2.2.13 RLTP Availability And Continuity For Integrate D-114
D.11.2.2.2.14 RLTP Availability For Integrate D-114
D.11.2.2.2.15 RLTP Continuity For Integrate D-115
D.12 OPA FOR AIR TAXI UAS REMOTE PILOT'S MANAGE C2 LINK SYSTEM ACTIVITY D-115
D.13 SUMMARY OF AIR TAXI UAS RESULTS OF THE ASSESSMENTS D-118
D.13.1.1 Transaction Expiration Times D-118
D.13.2 Summary Of The C2 Link System's Performance When Supporting The Remote Pilot's Aviate, Communicate, Navigate And Integrate Activities D-121
D.13.3 Summary Of The C2 Link System's Performance When Supporting The Remote Pilot's Manage C2 Link System Activity D-121
D.14 OPA ASSESSMENT FOR SMALL PACKAGE DELIVERY UAS SURFACE TAKEOFF AND LANDING OPERATIONS D-123
D.14.1 Non-Towered D-123
D.14.1.1 Corrupted Cause D-123
D.14.1.1.1 RLTP Integrity For Aviate D-123
D.14.1.1.2 RLTP Integrity For Navigate D-123
D.14.1.2 Interrupted Cause D-123
D.14.2 Towered D-123
D.15 OPA ASSESSMENT FOR SMALL PACKAGE DELIVERY UAS DEPARTURE AND ARRIVAL OPERATIONS D-124
D.16 OPA ASSESSMENT FOR SMALL PACKAGE DELIVERY UAS TRANSIT/EXTENDED OPERATIONS D-124
D.16.1 Class G AIRSPACE D-124
D.16.1.1 Corrupted Cause D-124
D.16.1.1.1.1 RLTP Integrity For Aviate D-124
D.16.1.1.1.2 RLTP Integrity For Navigate D-124
D.16.1.1.1.3 RLTP Integrity For Integrate D-124
D.16.1.2 Interrupted Cause D-125

D.16.1.2.1 Transaction Timelines....D-125
D.16.1.2.2 TET....D-125
D.16.1.2.2.1 DAA Maneuver For Separation Notification Not Received By Remote Pilot....D-125
D.16.1.2.2.2 Remote Pilot Initiated Maneuver Not Executed By UA In FGS Mode....D-125
D.16.1.2.2.3 Remote Pilot Initiated Maneuver Not Executed By UA In FMS Mode....D-126
D.16.1.2.3 RLTP Availability And Continuity For Aviate....D-126
D.16.1.2.3.1 RLTP Availability For Aviate....D-126
D.16.1.2.3.2 RLTP Continuity For Aviate....D-126
D.16.1.2.4 RLTP Availability And Continuity For Navigate....D-126
D.16.1.2.4.1 RLTP Availability For Navigate....D-126
D.16.1.2.4.2 RLTP Continuity For Navigate....D-126
D.16.1.2.5 RLTP Availability And Continuity For Integrate....D-126
D.16.1.2.5.1 RLTP Availability For Integrate....D-127
D.16.1.2.5.2 RLTP Continuity For Integrate....D-127
D.16.2 Controlled Airspace....D-127
D.16.2.1 Corrupted Cause....D-127
D.16.2.1.1 RLTP Integrity For Aviate....D-127
D.16.2.1.2 RLTP Integrity For Navigate....D-127
D.16.2.1.3 RLTP Integrity For Integrate....D-127
D.16.2.2 Interrupted Cause....D-128
D.16.2.2.1 Transaction Timelines....D-128
D.16.2.2.2 TET....D-128
D.16.2.2.2.1 DAA Initiated Maneuver For Separation Notification Not Received By Remote Pilot....D-128
D.16.2.2.3 Remote Pilot Initiated Maneuver Not Executed By UA In FGS Mode....D-128
D.16.2.2.3.1 Remote Pilot Initiated Maneuver Not Executed By UA In FMS Mode....D-128
D.16.2.2.4 RLTP Availability And Continuity For Aviate....D-128
D.16.2.2.4.1 RLTP Availability For Aviate....D-128
D.16.2.2.4.2 RLTP Continuity For Aviate....D-129
D.16.2.2.5 RLTP Availability And Continuity For Navigate....D-129
D.16.2.2.5.1 RLTP Availability For Navigate....D-129
D.16.2.2.5.2 RLTP Continuity For Navigate....D-129
D.16.2.2.6 RLTP Availability And Continuity For Integrate....D-129
D.16.2.2.6.1 RLTP Availability For Integrate....D-129
D.16.2.2.6.2 RLTP Continuity For Integrate....D-129
D.17 OPA FOR SMALL PACKAGE DELIVERY UAS REMOTE PILOT'S MANAGE C2 LINK SYSTEM ACTIVITY....D-130
D.18 SUMMARY OF SMALL PACKAGE DELIVERY UAS RESULTS OF THE ASSESSMENTS....D-133
D.18.1.1 Transaction Expiration Times....D-133
D.18.2 Summary Of SPD UAS C2 Link System's Performance When Supporting The Remote Pilot's Aviate, Communicate, NAVIGATE, And Integrate Activities....D-133
D.18.3 Summary Of SPD UAS C2 Link System's Performance When Supporting The Remote Pilot's Manage C2 Link System Activity....D-135
D.19 EXAMPLE OF AVAILABILITY, CONTINUITY, AND USE TIME CONSIDERATIONS....D-137
D.19.1 Overall OPA Considerations....D-139
D.20 REFERENCES....D-139

APPENDIX E C2 LINK SYSTEM USER DATA RATE CONSIDERATIONS....E-1

E.1 INTRODUCTION....E-1
E.2 INFORMATION FLOWS....E-2
E.3 C2 LINK SYSTEM USER DATA LOADING ESTIMATES....E-4

E.3.1 Aircraft Control E-4
E.3.2 Navaids E-4
E.3.3 ATC Voice Relay E-4
E.3.4 Target Data E-5
E.3.5 Weather Radar E-5
E.3.6 Non-Payload Video E-5
E.4 C2 LINK MANAGEMENT SYSTEM OVERHEAD AND THROUGHPUT E-6
E.4.1 Addressing/Networking Protocol And Security Overhead E-6
E.4.1.1 Message Packing For Aircraft Control And Navaids STANAG 4586 Messages E-8
E.4.1.2 Total Air/Ground Rf Link Data Rates (Aircraft Control/Navaids, ATC Voice Relay, Target Data) CE-9
E.4.2 C2 Link System Vs. Air/Ground RF Link User Data Throughput Requirements E-12
E.5 NOTIONAL C2 LINK SYSTEM SERVICE CLASSES E-15
E.6 EXAMPLE C2 LINK USER DATA MESSAGE SIZES AND CONTENT E-18
E.6.1 Aircraft Control Messages E-18
E.6.2 Navaids Messages E-30
E.6.3 Target Data Message Encoding E-34
E.7 REQUIRED TOTAL RF LINK USER DATA THROUGHPUT E-42
E.8 REFERENCES E-52

APPENDIX F RF LINK BUDGET CONSIDERATIONS FOR TERRESTRIAL AND SATELLITE-BASED C2 LINK SYSTEMS F-1

F.1 INTRODUCTION F-1
F.1.1 Causes Of Variability In RF Transmission Loss With Time F-1
F.1.1.1 The Propagation Medium Itself F-1
F.1.1.2 The Boundaries Of The Propagation Medium F-2
F.1.2 Additions To The Basic Free-Space Link Budget RF Transmission Loss F-2
F.1.3 Variability In The Basic Free-Space Link Budget RF Transmission Loss F-3
F.1.3.1 Fading F-3
F.1.3.2 Rain F-3
F.1.3.3 Scintillation F-4
F.1.4 The Interference-Free, Link Budget F-4
F.1.4.1 Effective Antenna Gains GETX And GERX F-4
F.1.4.2 Calculating The Es/No F-4
F.1.5 Interference Considerations F-5
F.1.6 Modeling And Simulation F-6
F.1.6.1 Propagation Modeling And Simulation F-6
F.1.6.2 Installed Antenna Modeling And Simulation F-9
F.1.6.3 Modeling And Simulation Of Fade Duration And Number Of Fades In The Time Frame Of Interest F-12
F.2 DETAILED TERRESTRIAL-BASED RF LINK BUDGET ANALYSIS F-13
F.2.1 Terrestrial-Based RF Links F-13
F.2.2 Time-Invariant Terrestrial Link Budget Elements F-14
F.2.2.1 EIRPSD And PFD Limitations F-14
F.2.2.2 Antenna Discrimination And Pointing Accuracy F-14
F.2.2.3 GRS And ARS Performance F-15
F.2.2.4 RF Transmission Loss F-15
F.2.3 Time-Variant Terrestrial Link Budget Elements F-15
F.2.3.1 Tropospheric Variability F-16
F.2.3.2 Surface Reflection F-16
F.2.3.3 Overall Fading Depths F-16
F.2.4 Availability And Interruption Time Predictions F-18
F.2.5 Other Terrestrial-Based RF Link Budget Considerations F-18

F.2.5.1 Required Es/No F-18
F.2.5.2 Interference F-20
F.2.6 Terrestrial Link Budget Templates F-20
F.2.6.1 C Band Link Forward Link F-20
F.2.6.2 C Band Link Return Link F-21
F.3 DETAILED SATELLITE-BASED RF LINK BUDGET ANALYSIS F-21
F.3.1 Satellite-Based RF Links F-22
F.3.2 Time-Invariant Satellite Link Budget Elements F-24
F.3.2.1 Off-Axis EIRPSD And PFD Limitations F-24
F.3.2.2 Earth Station Antenna Discrimination And Pointing Accuracy F-25
F.3.2.3 Satellite Transponder And Earth Station Performance F-25
F.3.2.4 RF Transmission Loss F-27
F.3.3 Time-Variant Satellite Link Budget Elements F-28
F.3.4 Availability And Interruption Time Predictions F-29
F.3.5 Other Satellite Link Budget Considerations F-31
F.3.5.1 Required Es/No F-31
F.3.5.2 Interference F-31
F.3.6 Satellite Link Budget Templates F-31
F.3.6.1 Ku Band Link 1 ..... F-32
F.3.6.2 Ku Band Link 2 ..... F-33
F.3.6.3 Ku Band Link 3 ..... F-34
F.3.6.4 Ku Band Link 4 ..... F-35
F.3.6.5 Ka Band Link 1 ..... F-36
F.3.6.6 Ka Band Link 2 ..... F-37
F.3.6.7 Ka Band Link 3 ..... F-38
F.3.6.8 Ka Band Link 4 ..... F-38
F.4 REFERENCES F-39

APPENDIX G GROUND/GROUND LINK CONSIDERATIONS G-1

G.1 INTRODUCTION G-1
G.2 SUMMARY OF AIR/GROUND AND GROUND/GROUND LINKS G-2
G.3 GROUND/GROUND LINKS G-3
G.3.1 Direct Connections G-3
G.3.2 Networked Connections G-3
G.3.2.1.1 Public Networks G-3
G.3.2.1.2 Virtual Private Network Connection Over The Internet G-3
G.3.2.1.3 A Secure Wireless Network Connection G-4
G.3.2.2 A Private Network Connection G-4
G.4 FACTORS TO CONSIDER WHEN SELECTING A GROUND/GROUND LINK PROVIDER OR DEVELOPING A GROUND/GROUND LINK G-4
G.4.1 The Requirements In Section 3 ..... G-4
G.4.2 Use Of Service Level Agreements G-5

APPENDIX H UNCREWED AIRCRAFT SYSTEMS (UAS) COMMAND AND CONTROL (C2) CONNECTIVITY USING SATCOM LINKS (L, C, KA, AND KU BAND) H-1

H.1 INTRODUCTION H-1
H.2 COMMUNICATION SATELLITES H-1
H.3 L BAND SATELLITE COMMUNICATIONS H-2
H.3.1 Introduction To L Band Satellites H-2
H.3.2 AMSS And AMS(R)S Systems H-2
H.4 C BAND SATELLITE COMMUNICATIONS H-3
H.5 KA AND KU BAND SATELLITE COMMUNICATIONS H-3

H.5.1 Introduction To Ka And Ku Band Systems H-3
H.5.2 Fixed Satellite Service Geostationary Satellites (Resolution 155 Compliant) H-4
H.5.3 High Throughput Satellites (HTS) H-5
H.5.4 Non-Geo Satellites H-5
H.5.5 References H-5

APPENDIX I SERVICE LEVEL AGREEMENTS AND CONRACTS (TERRESTRIAL/SATCOM) I-1

I.1 INTRODUCTION I-1
I.1.1 Stakeholders In The C2 Link System Service Provision Performance I-1
I.2 C2 LINK SERVICE STAKEHOLDERS AND ASSOCIATED ROLES AND RESPONSIBILITIES I-2
I.2.1 C2CSP Structure Options I-2
I.2.2 Multiple Service Level Agreements I-4
I.3 SERVICE DELIVERY AND C2CSP OVERSIGHT I-4
I.3.1 Monitoring And Interference Reporting Requirements I-5
I.3.2 Safety Management Oversight Requirements I-5
I.4 SERVICE LEVEL AGREEMENTS (SLA) CONTENT I-5
I.5 REFERENCES I-6

APPENDIX J COMMAND AND CONTROL AND PAYLOAD ON SAME LINK J-1

J.1 INTRODUCTION J-1
J.2 APPLICABILITY OF C2 AND PAYLOAD INFORMATION ON THE SAME LINK J-1
J.3 METHODS TO SUPPORT C2 AND PAYLOAD DATA ON THE SAME LINK J-1
J.4 PRIORITIZATION AND THE C2 LINK J-2
J.5 PRIORITIZATION AND THE C2CSP J-3
J.6 SEPARATION OF PROTECTION DOMAINS J-3
J.6.1 Description Of C2CSP Encryption For End-To-End Domain Separation J-3
J.6.2 Inner And Outer Tunnel Functionality J-3
J.6.3 C2 And Payload Data Separation Communications Security Considerations J-4

APPENDIX K CONSIDERATIONS FOR C2 LINK SYSTEM CONNECTION, SWITCHOVER, AND CONTROL STATION HANDOVER K-1

K.1 INTRODUCTION K-1
K.2 DEFINITIONS K-2
K.3 C2 LINK SYSTEM OPERATIONAL ENVIRONMENT K-5
K.3.1 Example C2 Link System Switchover Scenarios K-5
K.3.2 Example Control Station Handover Scenarios K-5
K.3.3 Operational Considerations K-6
K.4 C2 LINK SYSTEM COMPONENTS OVERVIEW K-9
K.4.1 Air/Ground Link Types K-10
K.4.2 Ground/Ground Link Interconnection Types K-11
K.5 C2 LINK SYSTEM CONNECTIONS AND SWITCHOVERS K-11
K.5.1 Connection Description K-11
K.5.1.1 Connections Over Point-To-Point Links Versus Over Networked Links K-12
K.5.2 C2 Link System Switchovers K-15
K.5.2.1 “DTSR Subsystem Connection” Switchover (Optional Procedure 1) K-16
K.5.2.2 “C2 Link System Route” Switchover (Optional Procedure 2) K-20
K.5.2.3 Multilink Operations K-21
K.5.3 Switchover Hand-Shake Sequence K-22
K.5.3.1 DTSR Subsystem Connection Switchover Hand-Shake Sequence K-22

K.5.3.2 C2 Link System Route Switchover Hand-Shake Sequence K-26
K.5.4 Control Station Handovers K-28
K.5.4.1 Control Station Handover Using Ground Link Connection K-29
K.5.4.2 Control Station Handover Using Simultaneous C2 Link System Connections K-32
K.5.5 Control Station Handover Handshake Sequence K-34
K.5.5.1 Handshake Sequence For Handover Over Point-To-Point Terrestrial LOS Link K-34
K.5.5.2 Handshake Sequence For Handover Over Terrestrial Or SATCOM Air/Ground Access Network K-34
K.5.5.3 Handshake Sequence For CS Handover Using Ground Link Connection K-35
K.5.6 C2 Link Transmission Unit Size Selection K-37
K.6 INTERWORKING ASSESSMENT K-38
K.6.1 CS C2 Link Executive Management Functions K-39
K.6.1.1 Support Functions K-39
K.6.1.2 CS C2 Data Multiplexing/Demultiplexing And Prioritization Functions K-41
K.6.2 CS C2 Link System Data Transfer, Security And Routing (DTSR) Subsystem K-42
K.6.3 Ua C2 Link Executive Management Functions K-42
K.6.3.1 Support Functions K-42
K.6.3.2 UA C2 Data Multiplexing/Demultiplexing And Prioritization Functions K-43
K.6.4 UA C2 Link System Data Transfer, Security And Routing (DTSR) Subsystem K-43
K.7 C2 LINK SWITCHOVER AND CONTROL STATION HANDOVER SAFETY ASSESSMENT K-44
K.8 C2 LINK SYSTEM INTERWORKING REQUIREMENTS K-44
K.8.1 Minimum C2 Link System Connection Interworking Requirements K-45
K.8.2 C2 Link System Switchover Interworking Requirements K-49
K.8.2.1 DTSR Subsystem Connection Switchover Interworking Requirements (Optional Procedure 1) K-50
K.8.2.2 C2 Link System Route Switchover Interworking Requirements (Optional Procedure 2) K-52
K.8.3 Control Station Handover Interworking Requirements K-54
K.8.4 C2 Link Switchover And Control Station Handover Related Recommendations K-57

APPENDIX L C2 LINK SYSTEM SECURITY CONSIDERATIONS L-1

L.1 INTRODUCTION L-1
L.2 DEFINITIONS L-1
L.3 C2 LINK SYSTEM COMMUNICATIONS SECURITY CONTEXT L-1
L.3.1 Terrestrial And SATCOM Point-To-Point Links L-2
L.3.2 Links Over Terrestrial And SATCOM Air/Ground Access Networks L-3
L.4 SECURITY REQUIREMENTS AND ACCEPTABLE MEANS OF COMPLIANCE (MOC) L-3
L.5 SECURITY CONTROLS OVERHEAD MITIGATION L-12
L.6 REFERENCES L-13

APPENDIX M VIDEO CONSIDERATIONS FOR UNCREWED AIRCRAFT OPERATIONS . M-1

M.1 INTRODUCTION M-1
M.2 STEP 1 – IDENTIFYING VISUAL REQUIREMENTS M-1
M.3 STEP 2 – IS VIDEO THE MOST APPROPRIATE TECHNIQUE TO SUPPORT THE FUNCTION? M-2
M.4 STEP 3 – SAFETY ASSESSMENTS M-4
M.5 STEP 4 – REQUIRED VIDEO PERFORMANCE AND SUPPORTING DATA RATE M-4
M.6 CONCLUSION M-6
M.7 REFERENCES M-6

APPENDIX N ACRONYMS, TERMINOLOGY, AND DEFINITIONS.....N-1

LIST OF TABLES

Table 3-1: Requirements Traceability and Abbreviations 16
Table 3-2: Operational Requirement OR-1 41
Table 3-3: Operational Requirement OR-2 41
Table 3-4: Operational Requirement OR-3 41
Table 3-5: Operational Requirement OR-4 42
Table 3-6: Functional Requirement FR-1 43
Table 3-7: Functional Requirement FR-2 43
Table 3-8: Functional Requirement FR-3 44
Table 3-9: C2 Link System Connection Interworking Requirements 45
Table 3-10: C2 Link System Common Switchover Interworking Requirements 49
Table 3-11: Optional Procedure 1 DTSR Subsystem Connection Switchover Interworking Requirements 50
Table 3-12: Optional Procedure 2 C2 Link System Route Switchover Interworking Requirements 51
Table 3-13: Interworking Requirements for CS Handovers 52
Table 3-14: Operational Hazards for Conventional UAS FR-1 55
Table 3-15: Conventional UAS - Safety Objectives for FR-1 65
Table 3-16: Conventional UAS - Safety Objectives for FR-3 67
Table 3-17: Air Taxi UAS - Safety Objectives for FR-1 68
Table 3-18: Air Taxi UAS - Safety Objectives for FR-2 72
Table 3-19: Air Taxi UAS - Safety Objectives for FR-3 73
Table 3-20: Small Package Delivery UAS - Safety Objectives for FR-1 74
Table 3-21: Small Package Delivery Taxi UAS - Safety Objectives for FR-2 75
Table 3-22: Small Package Delivery Taxi UAS - Safety Objectives for FR-3 76
Table 3-23: C2 Link System Performance Requirements Surface Taxi, Non-Towered, Baseline 79
Table 3-24: C2 Link System Performance Requirements Surface Taxi, Non-Towered, Advanced 80
Table 3-25: C2 Link System Performance Requirements Surface Taxi, Towered, Baseline 81
Table 3-26: C2 Link System Performance Requirements Surface Taxi, Towered, Advanced 82
Table 3-27 C2 Link System Performance Requirements Surface Takeoff and Landing, Non-Towered, Baseline 83
Table 3-28: C2 Link System Performance Requirements Surface Takeoff and Landing, Non-Towered, Advanced 84
Table 3-29: C2 Link System Performance Requirements Surface Takeoff and Landing, Towered 85
Table 3-30: C2 Link System Performance Requirements Surface Takeoff and Landing, Towered 86
Table 3-31: C2 Link System Performance Requirements Departure and Arrival in Non-Towered Airspace 87
Table 3-32: C2 Link System Performance Requirements Departure and Arrival in Towered Airspace 88
Table 3-33: C2 Link System Performance Requirements Transit/Extended Operations in Class A Airspace 89
Table 3-34: C2 Link System Performance Requirements Transit/Extended Operations in Class B, C, and E Airspace 90
Table 3-35: C2 Link System Performance Requirements Transit/Extended Operations in Class G Airspace 91
Table 3-36: C2 Link System Performance Requirements RLTP Transit/Extended Operations in Class Oceanic A Airspace 93
Table 3-37: C2 Link System Performance Requirements Surface Takeoff and Landing, Non-Towered 94
Table 3-38: C2 Link System Performance Requirements Surface Takeoff and Landing, Towered 95
Table 3-39: C2 Link System Performance Requirements Departure and Arrival, Non-Towered 96
Table 3-40: C2 Link System Performance Requirements Departure and Arrival, Towered 97
Table 3-41: C2 Link System Performance Requirements Transit Extended Operations, Class B, C and E Airspace 98
Table 3-42: C2 Link System Performance Requirements Transit Extended Operations, in UAM corridors 99

Table 3-43: C2 Link System Performance Requirements Surface Takeoff and Landing, Non-Towered 100
Table 3-44: C2 Link System Performance Requirements Transit/Extended operations, Class G airspace 101
Table 3-45: C2 Link System Performance Requirements Transit/Extended operations, Controlled airspace 102
Table 3-46: Security Requirements for User Plane Traffic between Uncrewed Aircraft and Control Station 103
Table 3-47: Security Requirements for Control Plane Traffic between Uncrewed Aircraft and Control Station 106
Table 3-48: Security Requirements for User Plane Traffic over Connections between Uncrewed Aircraft and Air/Ground Network Gateway and between Control Station and Air/Ground Network Gateway 107
Table 3-49: Security Requirements and Recommendations for Control Plane Traffic over Connections between Uncrewed Aircraft and Air/Ground Network Gateway and between Control Station and Air/Ground Network Gateway 107
Table 3-50: Recommendations 108
Table 4-1: Identification and Definition of Test Actions 121
Table 4-2: Security Requiremnts VTM 140
Table 4-3: Internetworking Requirement VTM 163
Table A-1: CONOPS to be Studied A-29
Table B-1: Descriptions of the Developed OVs and SVs [[B-3]and [B-4]] B-3
Table C-1: List of Limitations to Scope and OSA General Assumptions C-6
Table C-2: List of Specific Assumptions (Also used for Existing Controls) C-12
Table C-3: Hazard Severity Classifications C-34
Table C-4 Required Likelihood Matrix C-36
Table C-5: Risk Assessment Matrix C-37
Table C-6: Risk Acceptance Criteria C-38
Table C-7: Standardized Lost C2 Link State Procedures C-40
Table C-8: Conventional Scenarios Most Stressful Corrupted Use Case/Information Exchanges for Aviate Hazards C-49
Table C-9: Conventional Scenarios Most Stressful Corrupted Use Case/Information Exchanges for Navigate Hazards C-55
Table C-10: Conventional Scenarios Most Stressful Corrupted Use Case/Information Exchanges for Integrate Hazards C-61
Table C-11: Conventional Scenarios Most Stressful Interrupted Use Case/Information Exchanges for Aviate Hazards C-71
Table C-12: Conventional Scenarios Most Stressful Interrupted Use Case/Information Exchanges for Communicate Hazards Caused by Interrupted C2 Link C-81
Table C-13: Conventional Scenarios Most Stressful Interrupted Use Case/Information Exchanges for Navigate Hazards. C-89
Table C-14: Conventional Scenarios Most Stressful Interrupted Use Case/Information Exchanges for Integrate Hazards C-99
Table C-15: Most Stressful Air Taxi Use Case/Information Exchanges for Aviate Activity caused by a Corrupted C2 Link (scenarios C2-S3B and C2-S3C) C-108
Table C-16: Most Stressful Air Taxi Use Case/Information Exchanges for Communicate with Passengers Activity caused by a Corrupted C2 Link (scenarios C2-S3B and C2-S3C) C-112
Table C-17: Most Stressful Air Taxi Use Case/Information Exchanges for Navigate Activity caused by a Corrupted C2 Link (Scenarios C2-S3B and C2-S3C) C-114
Table C-18: Most Stressful Air Taxi Use Case/Information Exchanges for Integrate Activity caused by a Corrupted C2 Link (scenarios C2-S3B and C2-S3C) C-119
Table C-19: Most Stressful Air Taxi Use Case/Information Exchanges for Aviate Activity caused by an Interrupted C2 Link (scenarios C2-S3B and C2-S3C) C-121
Table C-20: Most Stressful Air Taxi Use Case/Information Exchanges for Communicate Activity caused by an Interrupted C2 Link (Scenarios C2-S3B and C2-S3C) C-125

Table C-21: Most Stressful Air Taxi Use Case/Information Exchanges for Communicate with Passengers Activity caused by an Interrupted C2 Link (scenarios C2-S3B and C2-S3C) C-132
Table C-22: Most Stressful Air Taxi Use Case/Information Exchanges for Navigate Activity caused by an Interrupted C2 Link (Scenarios C2-S3B and C2-S3C) C-134
Table C-23: Most Stressful Air Taxi Use Case/Information Exchanges for Integrate activity caused by an Interrupted C2 Link (scenarios C2-S3B and C2-S3C)..... C-139
Table C-24: Most Stressful Small Package Delivery Corrupted Use Case/Information Exchanges for Aviate Activity..... C-142
Table C-25: Most Stressful Small Package Delivery Corrupted Use Case/Information Exchanges for Navigate Activity..... C-145
Table C-26: Most Stressful Small Package Delivery Corrupted Use Case/Information Exchanges for Integrate Activity C-147
Table C-27: Most Stressful Small Package Delivery Interrupted Use Case/Information Exchanges for Aviate Activity..... C-149
Table C-28: Most Stressful Small Package Delivery Interrupted Use Case/Information Exchanges for Navigate Activity..... C-151
Table C-29: Most Stressful Small Package Delivery Interrupted Use Case/Information Exchanges for Integrate Activity C-154
Table C-30: Conventional Operations Most Stressful Use Case/Information Exchanges for Manage C2 Link Hazards Caused by Misdirected C2 Link Establishment/Terminate; Switchovers or Handovers C-157
Table C-31: Conventional Operations Use Case/Information Exchanges for Manage C2 Link Hazards Caused by Failed C2 Link Establishment/Termination; Switchovers and Handovers C-161
Table C-32: Air Taxi Most Stressful Use Case/Information Exchanges for Manage C2 Link Hazards Caused by Misdirected C2 Link Establishment/Terminate C-165
Table C-33: Air Taxi Most Stressful Use Case/Information Exchanges for Manage C2 Link Hazards Caused by Failed C2 Link Establishment/Terminate C-168
Table C-34: SPD Most Stressful Use Case/Information Exchanges for Manage C2 Link Hazards Caused by Misdirected C2 Link Establishment/Terminate C-170
Table C-35: SPD Most Stressful Use Case/Information Exchanges for Manage C2 Link Hazards Caused by Failed C2 Link Establishment/Terminate C-172
Table C-36: Most Stressful Use Case/Information Exchanges for Conventional Operations Manage C2 Link Hazards Caused by Erroneous Status Report C-174
Table C-37: Most Stressful Use Case/Information Exchanges for Air Taxi Operations Manage C2 Link Hazards Caused by Erroneous Status Report..... C-176
Table C-38: Most Stressful Use Case/Information Exchanges for SPD Operations Manage C2 Link Hazards Caused by Missing and Erroneous Status Report C-177
Table C-39: Use Case/Information Exchanges for Manage C2 Link Hazards Changes to Air/Ground Link and Ground/Ground Operating Parameters Failed and Erroneous for Conventional and Air Taxi Operations..... C-180
Table C-40: Operational Hazards for Conventional Aircraft for FR-1..... C-186
Table C-41: Safety Reuirement Residual Required Likelihoods for FR-1 Conventional Operations. C-198
Table C-42: Operational Hazards for Air Taxi Aircraft for FR-1..... C-211
Table C-43: Safety Reuirement Residual Required Likelihoods for FR-1 Air Taxi Operations. C-217
Table C-44: Operational Hazards for Small Package Delivery Aircraft for FR-1..... C-223
Table C-45: Safety Requirement Residual Required Likelihoods for FR-1 Small Package Delivery Operations. C-225
Table C-46: Conventional Operations - Operational Hazards for FR-2 ..... C-229
Table C-47: - Safety Requirement Residual Required Likelihoods for Conventional Operations FR-2... C-231
Table C-48: Air Taxi Operations - Operational Hazards for FR-2 ..... C-234
Table C-49: Air Taxi Operations - Residual Required Likelihoods for FR-2 ..... C-235
Table C-50: Small Package Delivery Operations - Operational Hazards for FR-2 ..... C-236
Table C-52: Conventional Operations - Operational Hazards for FR-3 ..... C-239

Table C-53: - Safety Requirements Residual Required Likelihoods for Conventional Operations FR-3 . C-241
Table C-54: Air Taxi Operations - Operational Hazards for FR-3 ..... C-243
Table C-55: Safety Requirements ResidUal Required Likelihoods for Air Taxi Operations FR-3..... C-244
Table C-56: SPD Operations - Operational Hazards for FR-3 ..... C-245
Table C-57: Safety Requirement Residual Required Likelihoods for SPD Operations FR-3 ..... C-246
Table C-58: Summary of CFR Concerning Pilot Responsibility for Traffic Avoidance..... C-248
Table C-59: Summary of ATC Requirements C-256
Table D-1: Overview of the Organization of Appendix D.3, D.4, D.5, and D6 for Conventional UAS . D-9
Table D-10: Latency Estimates - Networked Terrestrial C2 Link Systems..... D-25
Table D-11: Latency Estimate – Networked Satellite C2 Link Systems D-26
Table D-12: Latency Standards for Various NAS Voice Equipment D-29
Table D-13: Manage C2 Link System Use Cases Organized by Phase of Flight Grouping, Airspace, and Remote Pilot Activity for FR-2..... D-79
Table D-15: Conventional UAS - Summary of Transaction Expiration Times..... D-92
Table D-16: Conventional UAS Summary of OPA Results for the Remote Pilot's Aviate, Communicate, Navigate and Integrate Activity - FR-1..... D-93
Table D-17: Conventional UAS - Summary of OPA Results for the Remote Pilot's Manage C2 Link Activity - FR-2..... D-97
Table D-18: Conventional UAS - Summary of OPA Results for the Remote Pilot's Manage C2 Link Activity - FR-3..... D-98
Table D-19: Air Taxi UAS - Manage C2 Link System Use Cases Organized by Phase of Flight Grouping, Airspace, and Remote Pilot Activity for FR-2..... D-116
Table D-20: Air Taxi UAS - Manage C2 Link System Use Cases Organized by Phase of Flight Grouping, Airspace, and Remote Pilot Activity for FR-3..... D-117
Table D-21: Air Taxi UAS - Summary of Transaction Expiration Times..... D-119
Table D-22: Air Taxi UAS - Summary of OPA Results for the Remote Pilot's Aviate, Communicate, Navigate and Integrate Activity - FR-1..... D-120
Table D-23: Air Taxi UAS – Summary of Results for the Remote Pilot's Manage C2 Link Activity - FR-2 ..... D-122
Table D-24: Air Taxi UAS – Summary of Results for the Remote Pilot's Manage C2 Link Activity - FR-3 ..... D-122
Table D-25: Small Package Delivery UAS - Manage C2 Link System Use Cases Organized by Phase of Flight Grouping, Airspace, and Remote Pilot Activity for FR-2..... D-131
Table D-26: Small Package Delivery UAS - Manage C2 Link System Use Cases Organized by Phase of Flight Grouping, Airspace, and Remote Pilot Activity for FR-3..... D-132
Table D-27: Small Package Delivery UAS – Summary of Transaction Expiration Times D-134
Table D-28: Small Package Delivery UAS – Summary of OPA Results for the Remote Pilot's Aviate, Communicate, Navigate and Integrate Activity - FR-1 ..... D-134
Table D-29: Small Package Delivery UAS – Summary of Results for the Remote Pilot's Manage C2 Link Activity - FR-2 ..... D-136
Table D-30: Small Package Delivery UAS – Summary of Results for the Remote Pilot's Manage C2 Link Activity - FR-3 ..... D-136
Table E-1: Total Air/Ground RF Link User Data Throughput for Descent/Landing Phase – Return Link Manual Mode..... E-11
Table E-2: Estimated Non-Payload Throughput Requirements (bytes/sec) of a Single UA – Manual Mode E-13
Table E-3: Estimated Non-Payload Throughput Requirements (bytes/sec) of a Single UA – Automatic Mode E-14
Table E-4: C2 Link System Service Classes and Minimum Data Throughput – Manual Mode E-16
Table E-5: C2 Link System Service Classes and Minimum Data Throughput – Automatic Mode..... E-17
Table E-7: STANAG 4586 Aircraft Control Message Lengths by Phase of Flight..... E-19
Table E-8: Aircraft Control Messages, Takeoff/Climbout Phase: Forward..... E-20
Table E-9: Aircraft Control Messages, Takeoff/Climbout Phase: Return E-22

Table E-10: Aircraft Control Messages, En Route Phase: Forward E-24
Table E-11: Aircraft Control Messages, En Route Phase: Return E-25
Table E-12: Aircraft Control Messages, Descent/Landing Phase: Forward E-26
Table E-13: Aircraft Control Messages, Descent/Landing Phase: Return E-28
Table E-14: STANAG 4586 Navaids Message Lengths by Phase of Flight E-30
Table E-15: Navaids Messages, Takeoff/Climbout Phase: Forward E-31
Table E-16: Navaids Messages, Takeoff/Climbout Phase: Return E-31
Table E-17: Navaids Messages, En Route Phase: Forward E-32
Table E-18: Navaids Messages, En Route Phase: Return E-32
Table E-19: Navaids Messages, Descent/Landing Phase: Forward E-33
Table E-20: Navaids Messages, Descent/Landing Phase: Return E-33
Table E-21: Single Target Data Block (Relative Position) E-34
Table E-22: Single Target Data Block (Absolute Position) E-38
Table E-23: Total RF Link User Data Throughput for Takeoff/Climbout Phase – Forward Manual Mode E-43
Table E-24: Total RF Link User Data Throughput for Takeoff/Climbout Phase – Return Manual Mode.. ..... E-43
Table E-25: Total RF Link User Data Throughput for Takeoff/Climbout Phase – Forward Automatic Mode E-44
Table E-26: Total RF Link User Data Throughput for Takeoff/Climbout Phase – Return Automatic Mode E-45
Table E-27: Total RF Link User Data Throughput for En Route Phase – Forward Manual Mode E-47
Table E-28: Total RF Link User Data Throughput for En Route Phase – Return Manual Mode E-47
Table E-29: Total RF Link User Data Throughput for En Route Phase – Forward Automatic Mode .. E-48
Table E-30: Total RF Link User Data Throughput for En Route Phase – Return Automatic Mode E-48
Table E-31: Total RF Link User Data Throughput for Descent/Landing Phase – Forward Manual Mode……..E-49
Table E-32: Total RF Link User Data Throughput for Descent/Landing Phase – Return Manual Mode ..... …E-50
Table E-33: Total RF Link User Data Throughput for Descent/Landing Phase – Forward Automatic Mode E-51
Table E-34: Total RF Link User Data Throughput for Descent/Landing Phase – Return Automatic Mode E-51
Table F-1: C Band Forward Link Budget F-20
Table F-2: C Band Return Link Budget F-21
Table F-3: Ku Band Satellite and GES Performance Characteristics F-26
Table F-4: Ka Band Satellite and GES Performance Characteristics F-26
Table F-5: Ku Band AES Performance Characteristics F-27
Table F-6: Ka Band AES Performance Characteristics F-27
Table F-7: Clear-Sky Additional RF Transmission Loss F-27
Table F-8: Ku Band Link 1 ..... F-32
Table F-9: Ku Band Link 2 ..... F-33
Table F-10: Ku Band Link 3 ..... F-34
Table F-11: Ku Band Link F-35
Table F-12: Ka Band Link 1 ..... F-36
Table F-13: Ka Band Link 2 ..... F-37
Table F-14: Ka Band Link 3 ..... F-38
Table F-15: Ka Band Link 4 ..... F-38
Table K-1: Minimum C2 Link System Connection Interworking Requirements K-45
Table K-2: Minimum C2 Link System Switchover Interworking Requirements K-50
Table K-3: Optional Procedure 1 DTSR Subsystem Connection Switchover Interworking Requirements K-51
Table K-4: Optional Procedure 2 Summary of C2 Link System Route Switchover Interworking Requirements K-54

Table K-5: Summary of Interworking Requirements for CS Handovers..... K-55
Table K-6: C2 Link System Connection and Switchover Recommendations K-57
Table L-1: Summary of Security Requirements and MOCs for User Plane Traffic between Uncrewed Aircraft (UA) and Control Station (CS)..... L-6
Table L-2: Summary of Security Requirements and MOCs for Control Plane Traffic between Uncrewed Aircraft (UA) and Control station (CS) L-9
Table L-3: Summary of Security Requirements and MOCs for User Plane Traffic over Connections between Uncrewed Aircraft (UA) and Air/Ground Network Gateway and between Control Station (CS) and Air/Ground Network Gateway L-10
Table L-4: Summary of Security Requirements and MOCs for Control Plane Traffic over Connections between Uncrewed Aircraft (UA) and Air/Ground Network Gateway and between Control Station (CS) and Air/Ground Network Gateway L-11

LIST OF FIGURES

Figure 1-1: Systems Within and Beyond the C2 Link System Considered for UAS Operations within the U.S. Airspace 2
Figure 1-2: Document Sections and Appendices Relationships 4
Figure 3-1: Requirements Traceability 16
Figure 3-2: C2 Link System, Context, Scope and Boundaries 17
Figure 3-3: C2 Link System RLP in the Context of the C2 Link Specification and QoSR 19
Figure 4-1: User Data and Command & Status Messages Interfaces, CS Test Driver, UA Test Driver, CS DTSR, and UA DTSR Super Imposed on Figure K-17 in Appendix K 115
Figure A-1: Phases of Flight A-17
Figure A-2: Airspace Classification Descriptions A-19
Figure A-3: Local Linear Sensing Operational View (OV-1) A-30
Figure A-4: Local Cargo Delivery Operational View (OV-1) A-31
Figure A-5: Representative Extended Aerial Operations Operational View (OV-1) A-32
Figure A-6: Representative Extended Aerial Operations Operational View (OV-1) A-33
Figure A-7: Representative Automated SPD Scenario - Operational View (OV-1) A-34
Figure B-1: Overview of Coordinated Requirements Determination B-2
Figure B-2: Voice Communication Path Methods B-16
Figure B-3: Power Line Inspection Scenario Flight Profile and Use Case Locations B-27
Figure B-4: Flight Profile and Use Case Locations B-34
Figure B-5: Local Cargo Delivery Flight Profile B-40
Figure B-6-: Air Taxi Operations scenario C2-S3B, IFR route from a Towered Airport area to Downtown B-51
Figure B-7: Air Taxi Operations scenario C2-S3B, IFR return route from Downtown to Towered Airport. B-51
Figure B-8: Air Taxi Operations scenario C2-S3C, UAM Corridor route from a Towered Airport area to Downtown. B-52
Figure B-9: Air Taxi Operations scenario C2-S3C, UAM Corridor return route from Downtown to Towered Airport B-52
Figure B-10: Baseline Taxi System Interfaces B-65
Figure B-11: Advanced Taxi System Interfaces B-65
Figure B-12: Towered Airport Taxi-Out B-72
Figure B-13: Non-Towered Airport Taxi-In B-73
Figure B-14: Non-Towered Airport Taxi-Out B-73
Figure B-15: Towered Airport Taxi-In B-74
Figure B-16: Alaska Pipeline Inspection Flight Sequence and Airspace Structure B-84
Figure B-17: Alaska Pipeline Scenario Use Case Logical Sequential Order B-85
Figure B-18: CONOPS 3 Scenario 2 Flight Profile B-91
Figure B-19: Maritime Surveillance Scenario Use Case Logical Sequential Order B-92
Figure B-20: CONOPS 3 Scenario 3 Flight Profile B-97
Figure B-21: Coast to Coast Aerial Work Surveys Scenario Use Case Logical Sequential Order B-99
Figure B-22: Regional Cargo Delivery Flight Profile B-106
Figure B-23: HAPS Flight Profile B-112
Figure B-24: High Altitude Relay System Flight Profile B-119
Figure B-25: Flight Profile with Use Cases (Numbered Dots) Identified B-127
Figure B-26: OV-1 of a Representative UAS Mission B-133
Figure B-27: SV-1 – Possible C2 Link System Configurations B-136
Figure B-28A: Operational View of Terrestrial-Based and High Altitude Relay (HAR)-Based Air/Ground Links and the Ground/Ground Links B-138
Figure B-28B: Operational View of Satellite-Based Air/Ground Links and the Ground/Ground Links B-140
Figure B-29: Needed Information Exchanges - OV-2 ..... B-143

Figure B-30: OV-5: Operational Activity to Systems Function Traceability Matrix/System Mapping Function/System Traceability B-145
Figure B-31: SV-2: Systems Resource Flow Description/System Communication Description B-146
Figure B-32: SV-2: Systems Resource Flow Description Showing Two Control Station/System Communication Description B-150
Figure B-33: Revised Set of Phases of Flight Used in OV-3 Summary B-155
Figure C-1: Phases of Flight C-25
Figure C-2: Phases of Flight for VTOL Aircraft C-27
Figure D-1: Allowable Quantitative Probabilities for Qualitative Likelihoods from the ATO SMS Manual D-6
Figure D-2: C2 Link System, Context, Scope and Boundaries (Copy of Figure 3-2) D-24
Figure D-3: SV-2 for Voice Communications Relayed Through the UA D-29
Figure D-4: Example Unavailability versus Fade Duration for Certain Additional Loss D-138
Figure E-1: Basic Internal and External Non-Payload Information Flows of a UAS E-3
Figure E-2: Information Exchanges Between CS and UA E-3
Figure E-3: C2 Link System Block Diagram E-6
Figure E-4: Example Illustration of the Overhead Added to the C2 Link User Data E-7
Figure E-5: Combining Message Types E-9
Figure F-1: Example Terrestrial-Based RF Link Modeling and Simulation F-8
Figure F-2: Simulation of Antenna Installed on Aircraft F-10
Figure F-3: Cumulative Distribution Function of Aircraft Antenna Gains F-10
Figure F-4: Modeling of Installed Antenna Performance on a Generic Airframe F-11
Figure F-5: Directional Antenna Apparent Gain Reduction with Airframe Obstruction F-11
Figure F-6: Terrestrial-Based RF Link Architecture F-13
Figure F-7: Terrestrial Link Fading F-17
Figure F-8: Example Unavailability versus Fade Duration for Certain Additional Loss F-19
Figure F-9: Satellite-Based RF Link Architecture F-22
Figure F-10: Satellite link Coverage and Service Area F-22
Figure F-11: Satellite Link EIRPSD Limitations F-23
Figure F-12: Rain Rates, Percentages of Time, and Rain Regions F-28
Figure F-13: Example Unavailability versus Fade Duration for Certain Additional Loss F-30
Figure F-14: Example Unavailability versus Fade Duration for Certain Additional Loss F-30
Figure G-1: Options for Connecting a CS through Terrestrial and/or High-Altitude Relay Air/Ground Links to Reach a UA Under Its Control G-1
Figure G-2: Options for Connecting a CS through Satellite-Based Air/Ground Links to Reach a UA Under Its Control G-2
Figure H-1: Map of World ITU Regions H-4
Figure H-2: Resolution 155 Frequency Allocation Summary H-4
Figure I-1: RLP, C2 Link System Specification and QoS I-1
Figure I-2: C2CSP SLA example I-3
Figure I-3: SLA and Contract Example I-4
Figure J-1: End-to-End Domain Separation Recommended Approach J-3
Figure J-2: COMSEC Implementation J-4
Figure K-1: C2 Link System Air/Ground Link and Ground Interconnection Types K-1
Figure K-2: Example Functionality of Point-to-Point Air/Ground Links vs. Links over Air/Ground Networks K-13
Figure K-3: Switchover of the C2 Link System Connection Between Two Point-to-Point Links K-16
Figure K-4: Switchover of the DTSR Subsystem Connection Between Two Networked Links K-17
Figure K-5: Switchover of the DTSR Subsystem Connection Between a Point-to-Point Link and a Networked Link K-17
Figure K-6: “C2 Link System Route” Switchover Context Diagram K-20
Figure K-7: Make-Before-Break DTSR Subsystem Connection Switchover from a SATCOM Link to a Terrestrial Link K-23

Figure K-8: Make-Before-Break DTSR Subsystem Connection Switchover from a Terrestrial Link to a SATCOM Link K-24
Figure K-9: Break-Before-Make DTSR Subsystem Connection Switchover from a SATCOM Link to a Terrestrial Link K-25
Figure K-10: Break-Before-Make DTSR Subsystem Connection Switchover from a Terrestrial Link to a SATCOM Link K-26
Figure K-11: C2 Link System Route Switchover Sequence Diagram from Terrestrial to SATCOM K-27
Figure K-12: C2 Link System Route Switchover Sequence Diagram from SATCOM to Terrestrial K-28
Figure K-13: Control Station Handover Coordination: (a) via Ground Link; (b) via C2 Links K-30
Figure K-14: Control Station Handover Sequence Diagram via Point-to-Point Terrestrial LOS Links with Overlapping Coverage K-34
Figure K-15: Control Station Handover Sequence Diagram via Terrestrial or SATCOM Air/Ground Access Network when both CS can be Connected to UA K-35
Figure K-16A: Control Station Handover Sequence Diagram via Terrestrial or SATCOM Air/Ground Access Network when both CS are Connected to UA and Collaboration Between CS1 and CS2 Performed on Ground Connection K-36
Figure K-16B: Control Station Handover Sequence Diagram via Terrestrial or SATCOM Air/Ground Access Network when UA can Only Communicate with One CS at a Time and Collaboration Between CS1 and CS2 is Performed using Ground Connection K-37
Figure K-17: C2 Link System View Diagram K-39
Figure K-18: C2 Link Management System View Diagram with Two Control Stations and a Ground Link Between Them K-40
Figure K-19: C2 Link System View Diagram with Two Control Stations with No Ground Link Between Them K-41
Figure K-20: C2 Link System Interworking and Security Requirements Development Process Flow K-44
Figure L-1: C2 Link System Communications Security Context Diagram L-2

This Page Intentionally Left Blank

1 PURPOSE AND SCOPE

1.1 INTRODUCTION AND PURPOSE OF DOCUMENT

1.1.1 Introduction

This document presents and justifies the Minimum Aviation System Performance Standards (MASPS) for a Command and Control Link System (C2 Link System) used to monitor and control an Uncrewed Aircraft System (UAS). The C2 Link System carries the information exchanges between a Control Station (CS) and an Uncrewed Aircraft (UA). This MASPS is not the only way to determine such standards but is one that was determined to be viable by the members of Special Committee SC-228.

This B version of DO-377 is an expansion of the efforts in RTCA DO-377 [1] and DO-377A [2]. It adds an additional CONOPS, Low Altitude Delivery Supporting Small Package Delivery, and five new scenarios, two air taxi, two surface taxi and one small package delivery using advanced technologies. Accordingly there is expanded text in many of the appendices and additional requiremnts in Section 3. (See Section 1.3 for a description of the structure of this document.)

1.1.2 Purpose

This MASPS specifies the C2 Link System standards that should be useful to designers, manufacturers, installers, service providers, and users of UAS to support approval of C2 Link Systems intended for operational use within the United States (U.S.) Airspace. The C2 Link may make use of dedicated (point-to-point) links set up by the UAS operator, or it may make use of the services provided by a C2 Link Communication Service Provider (C2CSP), e.g., Mobile Network Operators such as Inmarsat, Iridium, terrestrial 4G or 5G mobile network operators, or any entity that builds a terrestrial network for use as a C2 Link System (See Appendix A.2.9). It is up to the UAS operator and the UAS designer which types of links to select to ensure that C2 Link Service is appropriate for the intended scenarios and airspace. Each of the links selected by the UAS operator and/or UAS designer are represented by links in Figure 1-1. The MASPS does not assume any specific design for the UA or the CS because of the wide variation found in current UAS designs. Consequently, this document is intended to provide information to support the determination of the specific performance requirements that will be applied to a UAS during the certification process.

 © 2023 RTCA, Inc.

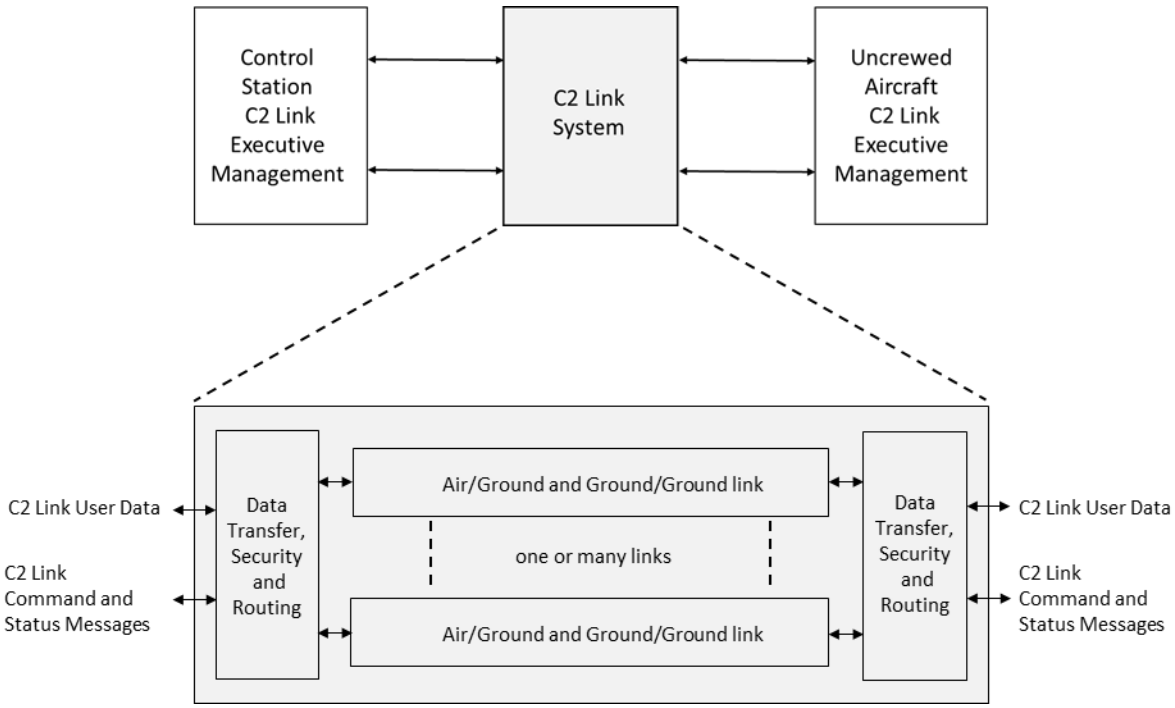


Figure 1-1: Systems Within and Beyond the C2 Link System Considered for UAS Operations within the U.S. Airspace

The MASPS also explains the process the Special Committee used to create these standards, which enables each UAS certification manufacturer, operator, or C2CSP Link Service Provider to tailor that process to support approval of their specific design. Because there are a variety of possible UAS designs and possible C2 Link Systems that can be used in those designs, this MASPS establishes requirements based on the airspace where the UAS is operating and type of the messages flowing across the C2 Link Systems. The purpose of the MASPS is to define C2 Link System standards that will be applicable to all UA operating within the scope of the various Concepts of Operations (CONOPS) defined in Appendix A. This is a different approach from other MASPS that started with requirements from the air navigation service provider and specific CONOPS for the use of communication systems (e.g., Controller Pilot Data Link Communications).

Compliance with these standards is recommended as one means of assuring that a C2 Link System and each of its subsystems will perform its intended function(s) satisfactorily under all conditions normally encountered in routine aeronautical operations for the environments intended. Additionally, the MASPS may be accepted as a means of compliance to regulations by one or more regulatory and/or advisory documents (e.g., advisory circulars, Technical Service Orders (TSOs), notices, etc.) and may be referenced in part or in total. Any regulatory application of this document is the sole responsibility of the appropriate certification authority.

1.2 SCOPE OF THE DOCUMENT

In developing these standards, SC-228 used the following Systems, Operations, and Regulatory scope:

1. Systems

The C2 Link System is defined as the connection used to send information exchanges between a CS and a UA and to manage the connection between them. The scope of this standard is shown in the shaded box in Figure 1-1. The figure shows that the C2 Link

System includes only the functionality required to support the Air/Ground and Ground/Ground links from the CS and the UA (Data Transfer, Security, and Routing (DTSR) in the CS and the UA and one or more possible links to the CS and the UA Executive Management capabilities. Appendices B.5.2 and B.5.3 describe the various types of links that may be included in a C2 Link System, and Appendix B.5.1 describes how different types of links may be used operationally. A detailed explanation of DTSR functions is found in Appendix K.6. Consequently, this MASPS does not address the content, prioritization, acknowledgment, frequency, or any other aspect of the User Data that flows over the links.

2. Operations

The scope of the operations considered all types of airspace used in the U.S. and Oceanic Airspace managed by the U.S. Air Traffic Organization (ATO) except Class E above A and transoceanic operations. The strategy used in writing this MASPS was to focus on enabling operations that are in high demand today or expected in the near future. Then those operational descriptions were used (a) to develop operational assumptions regarding capabilities of the UAS stakeholders and then (b) to begin building a more mature and comprehensive set of safety based performance assessments for those operations. More information on the airspaces covered in this MASPS is available in Appendix B. The specific CONOPS that were assessed are explained in detail in Appendix A, and the use cases and scenarios, are explained in Appendix B.

3. Regulatory

Federal Aviation Administration (FAA) regulations and procedures were used as a basis for determining the needed C2 Link System standards in this MASPS. The C2 Link System Operational Safety Assessment (OSA) (see Appendix C) in this MASPS is not intended to replace the complete UAS system safety analysis that is required by the FAA Type Certification Regulations (e.g., 14 CFR Part §25.1309 and Part §23.2500) but is intended to provide input into that system safety analysis. The OSA was used to support the development of the Operational Performance Assessment (OPA), and the OPA was used to create the requirements in Section 3 for scenarios addressed in Appendix B.

Design Assurance Levels (DAL) are not specified in this MASPS. This document is intended to establish the acceptable level of risk for C2 Link System functionality in the airspace where the UA is operating. The appropriate level of design assurance will vary greatly based on many factors that may include the level of UAS automation, C2 Link System redundancy, airspace where the UAS is intended to operate, the kinetic energy of the UA, and the population density under the approved area of operations. The trade space created by this many variables makes it impossible to establish fixed design assurance levels. This document is intended to inform the UAS designer and C2CSP how to create and obtain regulatory approval of designs that meet the acceptable level of safety risk for the UAS design and CONOPS.

This document is not applicable to UAS operations performed under the 14 CFR Part 107 regulations.

1.3 STRUCTURE OF THE DOCUMENT

The diagram below shows the general flow of the analysis conducted to create this document.

 © 2023 RTCA, Inc.