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

Minimum Operational Performance Standards for Airborne Collision Avoidance System Xu (ACAS Xu)

Volume I

RTCA DO-386
December 17, 2020

Prepared by: SC-147

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 147 (SC-147) jointly with EUROCAE WG-75 and approved by the RTCA Program Management Committee (PMC) on December 17, 2020.

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 functions as a Standards Development Organization and 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 for electronic systems and equipment that support aviation, and
- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunication Union and other appropriate international organizations can be based.

The organization's recommendations 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 and advisory circulars.

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 U.S. 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 1
1.1.1 Regulatory Context 1
1.1.2 Document Structure 2
1.1.2.1 Provisions for Potential Modifications 3
1.1.3 Intended Function 4
1.1.4 Operational Goals 4
1.1.5 Equipment 6
1.1.5.1 Aircraft Equipment Information Vulnerabilities 6
1.2 Background 7
1.2.1 Collision Avoidance Systems 7
1.2.1.1 TCAS II 7
1.2.1.2 ACAS X 8
1.2.1.2.1 ACAS Xa/Xo 8
1.2.1.2.2 ACAS Xu 9
1.3 System Overview 9
1.3.1 Surveillance and Tracking 11
1.3.2 Threat Resolution 12
1.3.3 Coordinating RAs Against ACAS-Equipped Threats 12
1.3.3.1 Future Coordination Schemes Supported by ACAS Xu 13
1.3.3.2 Multiple Threats, Sense and Intent, and Reversals 14
1.3.4 Control of Interference Caused by Active Surveillance 15
1.3.5 Provision of DAA Information to Ground Systems 15
1.3.6 Operation of ACAS Xu on the Airport Surface 16
1.3.7 Hybrid Surveillance and Extended Hybrid Surveillance 16
1.3.7.1 Overview 16
1.3.7.2 Description 16
1.3.7.2.1 Use When Taking Off/Airborne 19
1.3.7.2.2 Hybrid Surveillance When Operating On the Surface 20
1.3.8 Tracked Non-Cooperative Sensor Data 20
1.4 Assumptions and Limitations 21
1.4.1 Operational 21
1.4.1.1 Airworthiness 21
1.4.1.2 Improvements or Alternative Techniques 21
1.4.2 Environment 21
1.4.2.1 Transponders 21
1.4.2.2 ADS-B Systems 21
1.4.2.3 Interoperability with Onboard Aircraft Systems 22
1.4.2.4 Ownship Capability 22
1.4.2.4.1 Barometric Altimetry System 22
1.4.2.4.2 Mode S Transponder 22
1.4.2.4.3 Ownship Position Source 22
1.4.2.4.4 Aircraft Discretes 23
1.4.2.4.5 AGL Altitude 23
1.4.2.4.6 Heading 23
1.4.2.4.7 ATAR System 23
1.4.2.4.8 Use of ACAS Xu With Other Onboard Traffic Alerting Systems 23
1.4.2.4.9 Automatic Response 23
1.4.2.5 Aircraft Maneuver Performance 24
1.4.2.6 Command and Control (C2) Link Performance 25

1.5 Test Procedures 25
1.5.1 Environmental Tests 25
1.5.2 Bench Tests 25
1.5.3 Installed System Tests 25
1.5.4 Computer Performance Verification Test 26
1.5.5 Interoperability 26
1.5.6 DAA Compliance Tests 27
1.6 Configuration Control, Security and Distribution of the ACAS Xu Electronic Products 28
1.6.1 Configuration Control, Security and Distribution of ACAS Xu Parameter Data Item Files 28
1.6.1.1 Purpose 28
1.6.1.2 Overview and Guidelines 29
1.6.1.3 PDIF Details 29
1.6.2 Additional Electronic Products 30
1.7 Glossary of Terms 30
1.8 Abbreviations 38
1.9 References 42

2 ACAS Xu EQUIPMENT REQUIREMENTS AND TEST PROCEDURES 45

2.1 General Requirements 45
2.1.1 Airworthiness 45
2.1.2 General Performance 45
2.1.3 Federal Communications Commission Rules 45
2.1.4 Self-Test 45
2.1.5 Performance Monitoring 45
2.1.6 Interrogation Test Modes 45
2.1.7 Controls 46
2.1.7.1 Operation of Controls 46
2.1.7.2 Accessibility of Controls 46
2.1.7.3 Minimum Flight Crew Control Functions 46
2.1.8 Display Functions 47
2.1.9 Equipment Configuration 47
2.1.10 Mode S Transponder Capabilities 47
2.1.10.1 Performance Compatibility with Ownship ACAS Xu 47
2.1.11 ACAS Xu Combined with Other Aircraft Systems 48
2.1.12 Aural Annunciation 48
2.1.13 Shared Use of 1090 MHz Receiver with an ADS-B Receiving Subsystem 48
2.2 Minimum Performance Standards 48
2.2.1 Definition Of Standard Conditions 48
2.2.1.1 Measurement Conventions 49
2.2.1.2 Operational Environment 49
2.2.1.2.1 Aircraft Density 49
2.2.1.2.2 Aircraft Equipage 50
2.2.1.2.3 Interrogator Environment 50
2.2.1.2.4 Maximum Level Of ATCRBS Synchronous Garble Interference 52
2.2.1.2.5 Maximum Level Of Multipath Interference 52
2.2.1.3 Cooperative Target-Of-Interest 53
2.2.1.3.1 Maximum Closing Speed 53
2.2.1.3.2 Closing Speed As A Function Of Azimuth 53
2.2.1.3.3 Elevation Angle Relative To ACAS Xu 53
2.2.1.3.4 Altitude Relative To ACAS Xu 53
2.2.1.3.5 Minimum AGL Altitude 53
2.2.1.4 Non-Cooperative Target-Of-Interest 53
2.2.2 System Performance 54
2.2.2.1 Surveillance Range 54

2.2.2.1.1 For Generation Of RAs 54
2.2.2.1.2 For Generation Of RWC Alerting and Guidance 55
2.2.2.2 Surveillance Performance Objectives 55
2.2.2.2.1 General Surveillance Performance 55
2.2.2.2.2 Flight Test Surveillance Performance 56
2.2.2.2.3 Range Accuracy 56
2.2.2.2.4 Bearing Accuracy 56
2.2.3 Compatibility With Other Systems 56
2.2.3.1 Radiated Output Power 56
2.2.3.2 Unwanted Output Power 57
2.2.3.3 Interrogation Spectrum 57
2.2.3.4 Interrogation Jitter 57
2.2.3.5 Transmit Frequency And Tolerance 58
2.2.3.6 Interference Limiting 58
2.2.3.6.1 Interference Limiting Formulas 58
2.2.3.6.2 Interference Limiting Procedures 61
2.2.3.6.3 Interrogations From ACAS Xu On The Ground 62
2.2.3.6.4 Interrogations From ACAS Xu Above 18,000 Ft Barometric Altitud 63
2.2.3.7 Transmit Pulse Characteristics 63
2.2.3.7.1 Mode C Transmissions 63
2.2.3.7.2 Mode S Transmissions 64
2.2.3.8 Mode S Message Field Formats 66
2.2.3.8.1 Data Blocks 66
2.2.3.8.2 Format Structure 66
2.2.3.8.3 Field Descriptions 69
2.2.3.9 ACAS Xu Signal Protocol 111
2.2.3.9.1 Mode C Surveillance Signals 111
2.2.3.9.2 Mode S Surveillance Signals 112
2.2.3.9.3 Coordination with Other Aircraft 114
2.2.3.9.4 Communication of RA and RWC Guidance Information 121
2.2.3.9.5 Communication With Mode S [illegible]nd Sensors 125
2.2.3.9.6 Communication With Other G[illegible]nd Equipment 127
2.2.3.9.7 Extended Squitter With Aircraft Identification Message 128
2.2.3.10 Compatibility With Ow[illegible] Mode S Transponder 128
2.2.3.11 Aircraft Suppression [illegible]us 129
2.2.3.12 Interfaces With Other Systems 129
2.2.3.12.1 Mode S Transponder Related Interfaces 129
2.2.3.12.2 ACAS Xu Interface with Mode S Transponder 129
2.2.3.12.3 ACAS Xu Operating Mode Control 135
2.2.3.12.4 AGL Altitude Interface 135
2.2.3.12.5 Data Recording 136
2.2.3.12.6 Position Source Interface 137
2.2.3.12.7 Heading Interface 137
2.2.3.12.8 Air/Ground Interface 137
2.2.3.12.9 Displays & Controls System Interface 138
2.2.3.12.10 Non-Cooperative Sensors Interface 139
2.2.3.12.11 C2 Link 139
2.2.3.12.12 Receive Aircraft Maneuver Performance 140
2.2.4 Surveillance Requirements 140
2.2.4.1 Surveillance Update Rate 141
2.2.4.2 System Delay 141
2.2.4.3 Differential Channel Delay 141
2.2.4.4 Signal Reception 141
2.2.4.4.1 Receiver Sensitivity And Bandwidth 141

2.2.4.4.2 Reply Detection and Decoding 142
2.2.4.5 Interference Rejection and Control 146
2.2.4.5.1 Multipath Rejection 146
2.2.4.5.2 Narrow Pulse Rejection 147
2.2.4.5.3 TACAN and DME Signal Rejection 147
2.2.4.5.4 Control of ATCRBS Synchronous Garble 147
2.2.4.5.5 ATCRBS and Mode S FRUIT Rejection 159
2.2.4.6 Surveillance Tracking Requirements 159
2.2.4.6.1 Surveillance Target Track Capacity 160
2.2.4.6.2 Intruder Air/Ground Status Determination 161
2.2.4.6.3 Determination of Ownship Air-Ground Status 164
2.2.4.6.4 Range and Altitude Estimation 165
2.2.4.6.5 Non-Altitude Reporting Aircraft 186
2.2.4.6.6 Bearing Estimation 186
2.2.4.7 Antenna System 188
2.2.4.7.1 Polarization 188
2.2.4.7.2 Radiation Pattern 189
2.2.4.7.3 Use of a Directional Antenna for Mode S Interrogations 190
2.2.4.7.4 Antenna Selection 190
2.2.4.8 Relationship Between Front-End Surveillance and the STM 190
2.2.5 Surveillance and Tracking Module / Threat Resolution Module 191
2.2.5.1 STM – Surveillance and Tracking Module Overview 191
2.2.5.1.1 STM Tracking 191
2.2.5.1.2 STM Track Source Selection 192
2.2.5.1.3 STM/TRM Interface 198
2.2.5.1.4 ADS-B Validation for Alerting and Guidance 198
2.2.5.1.5 ADS-B Duplicate Address Processing 203
2.2.5.2 TRM - Threat Resolution Module Overview 205
2.2.5.2.1 State Estimation 208
2.2.5.2.2 Cost Estimation 211
2.2.5.2.3 Intruder Prioritization and Filtering for Horizontal Actions 212
2.2.5.2.4 Action Selection 212
2.2.5.2.5 Remain Well Clear (RWC) Band Determination 213
2.2.5.2.6 Coordination Selection 214
2.2.5.2.7 Display Logic Determination 215
2.2.5.3 General Integration Requirements 215
2.2.5.3.1 GenerateSTMReport 215
2.2.5.3.2 XuTRMUpdate 215
2.2.5.4 STM / Surveillance Correlation Requirements 216
2.2.5.5 Combined STM/TRM Input Interfaces 218
2.2.5.5.1 ReceiveBaroAltObservation 219
2.2.5.5.2 ReceiveRadAltObservation 220
2.2.5.5.3 ReceiveHeadingObservation 221
2.2.5.5.4 ReceiveWgs84Observation 222
2.2.5.5.5 ReceiveDiscretes 223
2.2.5.5.6 ReceiveDF0 224
2.2.5.5.7 ReceiveModeCReply 226
2.2.5.5.8 ReceiveModeCReplies 227
2.2.5.5.9 ReceiveStateVectorPosition 228
2.2.5.5.10 ReceiveStateVectorVelocity 230
2.2.5.5.11 ReceiveModeStatus 231
2.2.5.5.12 ReceiveUF16UDS30 233
2.2.5.5.13 ReceiveCapabilityReport 233
2.2.5.5.14 ReceiveXuATARReport 234

2.2.5.5.15 ReceiveStateVectorUATReport 235
2.2.5.5.16 ReceiveTargetDesignation 237
2.2.5.6 Combined STM/TRM Output Interfaces 237
2.2.5.6.1 STM/TRM Outputs to Display and Flight Control Systems 243
2.2.5.6.2 STM/TRM Outputs Used for Generating a Traffic Output 249
2.2.5.6.3 Data Transmitted by ACAS Xu on 1030 MHz 255
2.2.5.6.4 Data To Be Provided to Own Transponder 259
2.2.5.6.5 Data to Support Own Altitude Credibility Monitoring 262
2.2.5.6.6 TRMDesignationData Data (XuTRMReport.designation) 262
2.2.6 Displays and Controls 262
2.2.7 Monitor Requirements ..... 27[illegible]
2.2.7.1 General Requirements 280
2.2.7.1.1 Failure Response 280
2.2.7.1.2 Noninterference with Normal Operation 280
2.2.7.1.3 Self-Test 280
2.2.7.2 Monitoring of ACAS Xu Components 280
2.2.7.2.1 Computer Monitoring 280
2.2.7.2.2 Coordination Monitoring 281
2.2.7.2.3 ACAS Xu/Transponder Interface Monitoring 281
2.2.7.2.4 Altitude Input Monitoring 281
2.2.7.2.5 ICAO 24-Bit Aircraft Address 284
2.2.7.2.6 Monitoring of Transponder Status 284
2.2.7.2.7 Higher Priority Warning Systems 285
2.2.7.2.8 Monitoring of Ownship Position Source, Ground Speed, and Heading Input 285
2.2.7.2.9 Monitoring of ACAS Xu Transmitter and Receiver 287
2.2.7.2.10 Monitoring of ATAR 287
2.2.7.2.11 Monitoring of UAT 287
2.2.7.2.12 Monitoring of Own RI Value 287
2.2.7.3 Monitor Interfaces 288
2.2.7.3.1 Data Provided by the Monitor to Front-End Surveillance 288
2.2.7.3.2 Data Provided by the Monitor to the STM 288
2.2.7.3.3 Data Received by the Monitor from the STM 288
2.2.7.3.4 Data Received by the Monitor from the Control Panel via the Mode S Transponder 288
2.2.7.3.5 Data Received by the Monitor from Ownship Position Source 288
2.2.7.3.6 Data Received by the Monitor from Ownship Heading Source 288
2.2.7.3.7 Data Received by the Monitor from ATAR 288
2.2.7.3.8 Data Received by the Monitor from UAT 288
2.2.8 ACAS Xo 289
2.3 Equipment Performance - Environmental Conditions 290
2.3.1 Environmental Test Conditions 290
2.4 Equipment Test Procedures 294
2.4.1 Definitions of Terms and Conditions of Test 294
2.4.1.1 Standard Test Signals 296
2.4.1.2 Test Equipment Capabilities 297
2.4.1.3 Alternative Mode S Transponder Procedures 303
2.4.1.4 Bench Test Coverage of the TCAS Software 303
2.4.2 Detailed Test Procedures 304
2.4.2.1 Surveillance 304
2.4.2.1.1 Transmitter Characteristics 304
2.4.2.1.2 Receiver Characteristics (§2.2.4.4.1) 321
2.4.2.1.3 Reply Link Interference (§2.2.4.5.1.2) 330
2.4.2.1.4 Mode C Reply Reception (§2.2.4.4.2.1) 335
2.4.2.1.5 Mode S Squitter and Reply Reception (§2.2.4.4.2.2) 344
2.4.2.1.6 Mode C Target Surveillance Performance (§2.2.4.6.4) 351

2.4.2.1.7 Mode S Target Surveillance Performance (§2.2.4.6.4.2, §2.2.4.4.2.2) 368
2.4.2.1.8 Combined Mode S and Mode C Surveillance 401
2.4.2.1.9 Bearing Estimation 405
2.4.2.1.10 ACAS Xu Antenna System 412
2.4.2.2 Test Suite Test Procedures 415
2.4.2.2.1 Encounter Input Files 417
2.4.2.2.2 Encounter Output Files 422
2.4.2.2.3 Prescriptive/Mandatory Vs. Suggestive/Optional Algorithms 441
2.4.2.2.4 Defensive Code Branches and Deactivated Code 442
2.4.2.2.5 Detailed Test Suite Encounter List 445
2.4.2.3 External Parameter Selection (§2.2.3.9.5.3, §2.2.3.12.2.2.1, §2.2.3.12.2.2.4) 447
2.4.2.3.1 Ground Control of Sensitivity Level (§2.2.3.8.3.2.6, §2.2.3.12.2.3.2) 447
2.4.2.3.2 Surveillance-Only and Standby Mode Selection (§2.1.7.3, §2.2.3.12.3) 448
2.4.2.4 Coordination 450
2.4.2.4.1 Transmission of RA Report to Mode S Sensor (§2.2.3.9.5.1, 2.2.3.12.2.2.3, 2.2.5.5.5) 451
2.4.2.4.2 Transmission of RA Broadcast Interrogation and RWC Broadcast Interrogation (§2.2.3.9.6.1) 461
2.4.2.4.3 Coordination with Active CAS 469
2.4.2.5 ACAS Xu Capability and Part Number Reporting (§2.2.3.9.5.3, §2.2.3.12.2.2.4, §2.2.3.12.2.2.1, §2.2.5.5.5) 543
2.4.2.6 Transmission of Low-level Descend Inhibit (LDI) Information in RA Messages (§2.2.3.8.3.2.3.1) 548
2.4.2.7 System Integration Tests (§2.2.5.5) 551
2.4.2.8 General Integration Tests (§2.2.7) 553
2.4.2.9 Automatic Performance Monitoring and Self Test (§2.2.7 553
2.4.2.9.1 Automatic Performance Monitoring (§2.2.7.1.2 553
2.4.2.9.2 Self-Test (§2.2.7.1.3) 557
2.4.2.10 Performance Compatibility with Ownship's Mode S Transponder 557
2.4.2.10.1 ACAS Xu to Mode S Transponder Interference (§2.1.10.1) 557
2.4.2.10.2 Mode S Transponder to ACAS Xu Interference (§2.2.3.10) 557
2.4.2.11 Tests Related to Passive Surveillance 557
2.4.2.11.1 General Scenario Description 557
2.4.2.11.2 Verification of Shared Use of 1090 MHz Receiver with an ADS-B Receiving Subsystem (§2.1.13) 561
2.4.2.11.3 Verification of Acquisition and Maintenance of Established Tracks Using Active Surveillance (§2.2.4.6.4.2.3.2) 562
2.4.2.11.4 Verification of Maintenance of Established Tracks Using Passive Surveillance (§2.2.4.6.4.2.3.1) 567
2.4.2.11.5 Verification of Requirements Related to Transitions Between Passive and Active Surveillance 589
2.4.2.11.6 Verification of Error Budget in Computing Slant Range from Passive Data (§2.2.4.6.4.2.3.1.11) 607
2.4.2.11.7 Surveillance Overload and Capacity Tests (§2.2.4.6.1.1, §2.2.4.6.4.2.3.2.5) 608
2.4.2.11.8 Surveillance Overload and Capacity Test (Mode S, Mode C, ADS-B, and ATAR) 609
2.4.2.11.9 Verification of Monitoring Requirements (§2.2.7.2) 610
2.4.2.11.10 Verification of On-Ground ACAS Xu Range Determination Using ADS-B (§2.2.4.6.4.2.4, §2.2.4.6.2.2.2) 611
2.4.2.11.11 Verification of DF=18 ADS-B and ADS-R Only Passive Surveillance (§2.2.3.8.3.2.8, §2.2.5.5.4, §2.2.5.5.9, §2.2.5.5.10) 614
2.4.2.11.12 Verification of Intruder ADS-B Reports to STM 620
2.4.2.11.13 Verification of Duplicate Address Processing 622
2.4.2.12 Tests Related to Correlation Performance (§2.2.5.4) 622
2.4.3 Computer Performance Verification (§2.2.7.2.1) 627
2.4.3.1 RAM Pattern Tests 627

2.4.3.2 CPU Instruction Tests 627
2.4.3.3 Program Memory Tests 627
2.4.3.4 CPU Input/Output Tests 627
2.4.3.5 CPU Timing Tests 627
2.4.4 Cross-Reference of Requirements and Associated Tests 628
3 INSTALLED EQUIPMENT PERFORMANCE 651
3.1 Test Conditions 651
3.1.1 Power Input 651
3.1.2 Associated Equipment 651
3.1.3 Environment 651
3.1.4 Adjustment of Equipment 651
3.2 Equipment Installation 651
3.2.1 Equipment Accessibility 651
3.2.2 Display Visibility 651
3.2.3 Interference 651
3.2.4 Physical Installation 651
3.2.5 Aircraft Power Source 652
3.2.6 Transmission Lines 652
3.2.7 Antenna Location 652
3.2.7.1 Minimum Distance from Other Antennas 652
3.2.8 Altimetry System 652
3.2.8.1 Barometric Altimetry Performance Required for ACAS Xu Operation 653
3.2.8.2 Altimetry System Error Assessment 654
3.2.8.3 Definitions 655
3.2.9 Use of Flight Director Cues for RA Guidance (§3.2.10.2) 656
3.2.10 Integration with Aircraft Flight Controls 656
3.2.10.1 Pitch Cues on PFD and HUD 656
3.2.10.2 Flight Director 656
3.2.10.3 Automatic Response to RAs 656
3.3 Minimum Installed Equipment Performance Requirements 656
3.4 Test Procedures for Installed Equipment Performance 657
3.4.1 Conformity Inspection 657
3.4.2 General Test Procedures 657
3.4.2.1 Equipment Function 657
3.4.2.2 Interference Effects (Ground Test) 657
3.4.2.2.1 Suppression Bus 657
3.4.2.3 Accessibility 658
3.4.2.4 Integration with Aircraft Flight Controls 658
3.4.2.4.1 Flight Director (§3.2.10.2) 658
3.4.2.4.2 Auto Pilot (§3.2.10.3) 658
3.4.3 Antenna Gain Performance 658
3.4.3.1 Success Criteria 658
3.4.3.2 Full-Scale Anechoic Antenna Range Measurements of Gain 659
3.4.3.3 Scaled Model Measurements of Gain 659
3.4.3.3.1 Aircraft Model 659
3.4.3.3.2 Model Tests 659
3.4.3.4 Theoretical Calculations of Antenna Gain 660
3.4.3.4.1 Validation of Theoretical Calculations 660
3.4.3.5 Antenna Location Using Distance-Area Calculations 660
3.4.4 Certification Flight Test Procedures 661
3.4.4.1 Mode C Surveillance Flight Tests 661
3.4.4.2 Mode S Surveillance Flight Tests 663
3.4.4.3 Coordination Flight Tests 665

3.4.4.4 Passive Surveillance Flight Tests 666
3.4.5 Bearing Estimation Tests 667
3.4.5.1 Success Criteria for Bearing Estimation Measurements 667
3.4.5.2 Antenna Range Measurements of Bearing Accuracy 667
3.4.5.3 Airborne Measurements of Bearing Accuracy 669
3.4.5.4 Scaled Model Measurements of Bearing Accuracy 669
3.4.5.4.1 Aircraft Model 669
3.4.5.4.2 Antenna Model 669
3.4.5.4.3 Model Tests 669
3.4.5.5 Theoretical Calculations of Bearing Accuracy 670
3.4.5.5.1 Validation of Theoretical Calculations of Bearing Accuracy 670

4 Membership 671

APPENDIX A Surveillance Procedures A-1

A.1 Interference Limiting Procedure A-1
A.2 Rejection of Reply Link Interference A-4
A.3 Mode S Error Correction A-5
A.4 Determination of Synchronous Garble Potential A-11
A.5 Mode C Track Initiation A-18
A.6 Mode C Track Maintenance A-19
A.7 Multipath False Targets A-22
A.8 Mode S Squitter Processing A-22
A.9 Non-Altitude Reporting Aircraft A-23
A.10 Bearing Estimation A-25
A.11 Mode S Tracker Using a Five-Second Update Rate A-27
A.12 Transition from On-The-Ground to Airborne Interference Limiting A-28

APPENDIX B Appendix B: ACAS X RF Communication Paths B-1

B.1 Introduction B-1
B.2 Air-to-Air Communication B-1
B.2.1 Surveillance B-1
B.2.2 Coordination B-2
B.2.3 RA Broadcast Interrogation Messages B-2
B.3 Air-to-Ground, Ground-to-Air Communication B-4
B.3.1 Surveillance B-4
B.3.2 Sensitivity Level Command Messages (Ground-to-Air) B-4
B.3.3 RA Report (Air-to-Ground) B-4
B.3.4 Data Link Capability Report (Air-to-Ground) B-4
B.4 Communication Using Mode S Uplink Formats for Ground Monitoring B-5
B.4.1 RA Broadcast Interrogation Messages B-5
B.4.2 Remain Well Clear (RWC) Broadcast Interrogation Messages B-5

APPENDIX C Appendix C: Degraded Surveillance C-1

C.1 Introduction C-1
C.2 Analysis Overview C-1
C.2.1 Metrics C-1
C.2.2 Encounter Sets C-1
C.2.3 Analysis Methodology C-2
C.3 Analysis of Degraded Surveillance inputs C-2
C.3.1 ADS-B C-2
C.3.1.1 Quality C-3
C.3.1.1.1 NACp C-3
C.3.1.1.2 NACv C-5

C.3.1.2 Availability C-7
C.3.1.2.1 Gating C-7
C.3.1.2.2 Environmentally Reduced Update Rate C-8
C.3.1.2.3 Geometric Altitude C-10
C.3.2 Active C-12
C.3.2.1 Sensitivity to Stressing Bearing Error Models C-12
C.3.2.2 Environmentally Reduced Update Rate C-14
C.3.2.3 Bearingless C-16
C.3.3 Ownship C-17
C.3.3.1 Ownship Altitude Quantization C-17
C.3.3.2 Ownship Heading C-19
C.3.3.2.1 Track Angle Substitution C-19
C.3.3.2.2 WGS84 Timeout and Invalid Heading C-21
C.3.3.3 Noisy Ownship Measurements C-23
C.3.3.3.1 NACv C-23
C.3.3.3.2 NACp C-27
C.3.4 Effect of Mode S Surveillance Region on RWC/CA Alerting C-31
C.3.5 Impact of Degraded Analysis on Source Selection C-32
C.4 Summary C-36

APPENDIX D Appendix D: Conversion of Reported Positions to Slant Range D-1

D.1 Overview D-1
D.2 Exact Conversion Equations D-1
D.3 Height Above Ellipsoid vs. Barometric Altitude D-3
D.4 Spherical Earth Approximation D-4
D.5 Approximation Assuming N is the Same for All Aircraft D-5
D.6 Ellipsoidal Differential Approximation D-7
D.7 Spherical Differential Approximation D-11

APPENDIX E Appendix E: Analysis of Validation/Revalidation Range Tolerance Error Budget E-1

E.1 Introduction E-1
E.2 ACAS X Active Surveillance Range Error E-2
E.3 Own and Intruder Position Sensor Error E-2
E.4 Intruder Message LSB E-2
E.5 Uncompensated Latency in Intruder Position When Received by ACAS X E-2
E.6 Uncompensated Latency in Ownship Passive Position When Received by ACAS X E-3
E.7 Error Budget Allocated For Hybrid Surveillance Data Processing E-3
E.8 Sample Allocation of Hybrid Data Processing Errors E-3

APPENDIX F Appendix F: Test Suite Encounter List F-1

APPENDIX G Appendix G: Variable Validation Intervals G-1

G.1 Derivation of the Revalidation Time Interval G-1

APPENDIX H Appendix H: 1090 MHz Spectrum Reduction Analysis H-1

H.1 Introduction H-1
H.2 Simulation and Input Data Set H-1
H.3 Evaluate Algorithm Changes H-2
H.3.1 Algorithm Changes to RTCA DO-185B H-2
H.3.1.1 Reduced Surveillance Volume when Operating on Airport Surface H-2
H.3.1.2 Eliminating Range Monitoring Interrogations to On-Ground TCAS Aircraft when Own TCAS is on the Ground H-2
H.3.2 Algorithm Changes to RTCA DO-300 ..... H-3

H.3.2.1 Passively Monitor TCAS Aircraft when Below 2000 ft AGL H-3
H.3.2.2 Two Validation Attempts H-3
H.3.2.3 Variable Validation Rate H-3
H.3.2.4 Use of Short Replies for Validation H-4
H.3.2.5 Extended Hybrid Surveillance H-4
H.3.2.6 Passive Only Surveillance on the Ground H-5
H.4 Results H-5

APPENDIX I Appendix I: Air-to-Air Radar Accuracy Requirements I-1

I.1 Introduction I-1
I.2 ACAS Xu ATAR Input Interface I-1
I.3 ACAS Xu ATAR Observation Model I-2
I.4 ATAR Track Accuracy Requirements I-4
I.4.1 Background I-4
I.4.2 Derivation of Track Accuracy Requirements I-4
I.4.2.1 Assumptions I-4
I.4.2.2 Acceptability Criteria I-4
I.4.2.3 Method I-5
I.4.2.4 Surrogate Optimization Details I-6
I.4.3 Track Accuracy Requirements I-9
I.5 ATAR Track Uncertainty Requirements I-10
I.5.1 Background I-10
I.5.2 Derivation of Uncertainty Requirements I-11
I.5.3 Track Uncertainty Requirements I-3
I.6 ATAR Tracker Lag Requirements I-3
I.6.1 Background I-3
I.6.2 Derivation of Lag Requirements I-4
I.6.3 Tracker Lag Requirements I-6
I.7 Test Procedures I-7
I.7.1 Track Accuracy and Uncertainty (§I.4.3 and §I.5.3) I-8
I.7.2 Tracker Lag (§I.6.3) I-10
I.8 ACAS Xu Coordinate Conversions I-11
I.8.1 Function of Multiple Random Variables I-12
I.8.2 State Transformations I-12
I.8.2.1 Relative ENU to ACAS Xu ATAR Interface I-12
I.8.2.2 Relative ENU to Body-Aligned Spherical I-13
I.8.3 Full Derivation: Includes Ownship Attitude I-14
I.8.3.1 Nonlinear Function of Random Variables I-14
I.8.3.2 Requirements I-15
I.8.4 Simplified Derivations: Zero Bank/Pitch I-22
I.8.4.1 Nonlinear Function of Random Variables I-22
I.8.4.2 Requirements I-22
I.9 References I-26

APPENDIX J Appendix J: PDIF Life Cycle Process Flow and the Roles and Responsibilities of the Stakeholders J-1

J.1 PDIF Life Cycle Process Flow and the Roles and Responsibilities of the Stakeholders J-1

Table of Figures

Figure 1-1: ACAS Xu System Overview 10
Figure 1-2: Transition from Passive to Active Surveillance as a Function of Collision Potential 18
Figure 1-3: Extended Hybrid Surveillance State Transition Diagram (Ownship Taking Off / Airborne) .. 19
Figure 1-4: Extended Hybrid Surveillance State Transition Diagram (Ownship Operating on Surface) ... 20
Figure 2-1: Mode C-Only All-Call Interrogation Pulse Sequence for ACAS Xu 64
Figure 2-2: Mode S Interrogation Pulse Sequence For ACAS Xu 66
Figure 2-3: Mode S Interrogation or Uplink Formats Used by ACAS Xu 68
Figure 2-4: Mode S Reply or Downlink Formats Used by ACAS Xu 69
Figure 2-5: RF Transmissions Containing RA Information 123
Figure 2-6: RA Information Contained in the Part Two RF Transmissions 124
Figure 2-7: RWC Guidance Information Contained in the RF Transmissions 125
Figure 2-8: Mode C Reply 143
Figure 2-9: Mode S Reply 145
Figure 2-10: Minimum Basic Whisper-Shout Sequence 151
Figure 2-11: Timing For Six Power Steps In The Minimum Basic Whisper-Shout Sequence For Top Antenna Forward Beam 151
Figure 2-12: High Resolution Whisper-Shout Sequence 154
Figure 2-13: Surveillance Region State Transition Diagram 172
Figure 2-14: Example Coast Timeline 183
Figure 2-15: ACAS Xu STM Mode S Validation Scheme 201
Figure 2-16: ACAS Xu STM ATAR Validation Scheme 202
Figure 2-17: Primary Conceptual Blocks of TRM for Vertical and Horizontal Actions 206
Figure 2-18: High Level Process for Determining an Action 207
Figure 2-19: Transformation of Inputs 209
Figure 2-20: Estimation of Tau Distribution – Horizontal Entry Table 209
Figure 2-21: Sample Combining for Vertical Actions 210
Figure 2-22: Offline Cost Estimation for Vertical Actions – Cost Table Look-up 211
Figure 2-23: Vertical RWC Band Illustration 246
Figure 2-24 247
Figure 2-25 247
Figure 2-26: Horizontal RWC Band Illustration 249
Figure 2-27: Signal Relationship Between ACAS Xu, Mode S & Test Equipment 298
Figure 2-28: Definition Of Variables Associated With The Linear Movement Of Targets In The Range Dimension 301
Figure 2-29: Frequency Test Setup 305
Figure 2-30: Peak Power Test Setup 307
Figure 2-31: Whisper-Shout And Interrogation Rate Jitter Test Setup 309
Figure 2-32: Mode S Transmission Test Setup 315
Figure 2-33: DPSK Phase Reversal Tolerance Test Setup 316
Figure 2-34: Mode S RF Spectrum Test Setup 318
Figure 2-35: Unwanted Output Power Test Setup 320
Figure 2-36: Geometrical Illustration Of Multipath 354
Figure 2-37: Real Multipath 354
Figure 2-38: Simulated Multipath 355
Figure 2-39: Reply Sequence For Range Correlation Test Scenario A (Above 10 Kft) 357
Figure 2-40: Reply Sequence For Range Correlation Test Scenario B (Below 10 Kft) 358
Figure 2-41: Reply Sequence For Altitude Correlation Test 360
Figure 2-42: Range Vs. Time Plot For Intruders 1, 2, 23, And 24 367
Figure 3-1: Altimetry System Elements and Error Components 653
Figure 3-2: Ramp Test Geometry Considerations 668
Figure A-1: Interference Limiting Flow Diagram. A-3

Figure A-2: Initial Conditions For Error Detection. A-7
Figure A-3: Final Conditions Of Error Detection For 56 And 112 Bit Replies. A-8
Figure A-4: Initialization Of Error Pattern Location Logic For 56 And 112 Bit Replies. A-10
Figure A-5: Generation Of Correction Enable Bit. A-12
Figure A-6: Correction Of Decision Sequence. A-13
Figure A-7: Final State Of Error Correction Function. A-14
For L=0 if M was set, For L=1 if M was set (in parentheses) A-14
Figure A-8: Low Confidence Bit Measurement - Flow Diagram. A-15
Figure A-9: Intruder Range Track Comparison - Flow Diagram. A-17
Figure B-1: ACAS X Communications B-3
Figure C-1: NACp (Blended) C-4
Figure C-2: NACp (Horizontal Only – Worst-Case) C-5
Figure C-3: NACv (Blended) C-6
Figure C-4: NACv (Horizontal Only – Worst-Case) C-7
Figure C-5: Gating (Blended) C-8
Figure C-6: Reduced Update Interval for ADS-B Reports (Blended) C-9
Figure C-7: Reduced Update Interval for ADS-B Reports (Vertical Only) C-10
Figure C-8: Geometric Altitude (Blended) C-11
Figure C-9: Geometric Altitude (Vertical Only – Worst-Case) C-12
Figure C-10: HMM Bearing Errors (Blended) C-13
Figure C-11: HMM Bearing Errors (Horizontal Only – Worst-Case) C-14
Figure C-12: Active Update Delay (Blended) C-15
Figure C-13: Active Update Delay (Horizontal Only) C-16
Figure C-14: Bearingless (Vertical Only) C-17
Figure C-15: Ownship Coarse Altitude Quantization (Blended) C-18
Figure C-16: Ownship Coarse Altitude Quantization (Vertical Only – Worst-Case) C-19
Figure C-17: Track Angle Supplied as Ownship Heading (Blended) C-20
Figure C-18: Track Angle Supplied as Ownship Heading (Horizontal Only – Worst-Case) C-21
Figure C-19: WGS84 Timeout with Valid Heading (Vertical Only) C-22
Figure C-20: WGS84 Timeout with Invalid Heading (Vertical Only) C-23
Figure C-21: Ownship Passive Velocity Noise (Blended) C-24
Figure C-22: Ownship Active Velocity Noise (Blended) C-25
Figure C-23: Ownship Passive Velocity Noise (Horizontal Only – Worst-Case) C-26
Figure C-24: Ownship Active Velocity Noise (Horizontal Only – Worst-Case) C-27
Figure C-25: Ownship Passive Position Noise (Blended) C-28
Figure C-26: Ownship Active Position Noise (Blended) C-29
Figure C-27: Ownship Passive Position Noise (Horizontal Only – Worst-Case) C-30
Figure C-28: Ownship Active Position Noise (Horizontal Only – Worst-Case) C-31
Figure C-29: Active Surveillance (Blended, RWC/CA) vs. ATAR Surveillance (Blended, RWC/CA) C-33
Figure C-30: Active Surveillance (Horizontal Only, RWC/CA) vs. ATAR Surveillance (Blended, RWC/CA) C-34
Figure C-31: ADS-B Surveillance (Horizontal Only, RWC Only) vs. Active Surveillance (Horizontal Only, RWC/CA) C-35
Figure I-1: Class B Radar Coordinate Frame I-1
Figure I-2: ACAS Xu ATAR Observation Model I-3
Figure I-3: ACAS Xu ATAR Observation Model - Tracker Lag Model I-4
Figure I-4: Surrogate-Based Optimization - System Metric Distributions (Run 5.3 Response Values) I-7
Figure I-5: Reported Uncertainty Sweep Results – Raw 1
Figure I-6: Reported Uncertainty Sweep Results - With Accuracy Limits Imposed 2
Figure I-7: pNMAC and pAlert vs Process Noise I-5
Figure I-8: pReversal Horizontal and Vertical vs Process Noise I-5
Figure J-1: Creation, Configuration Control and Distribution of Revised ACAS X Equipment J-2

Table of Tables

Table 1-1: DO-365 Test Procedures Considered During Design of ACAS Xu 28
Table 2-1: Assumptions About Aircraft Density 50
Table 2-2: Maximum ATCRBS FRUIT Rate 51
Table 2-3: Maximum Mode S FRUIT Rates 51
Table 2-4: Interrogation Spectrum 57
Table 2-5: Mode C Pulse Shapes 64
(All values in microseconds) 64
Table 2-6: Mode S Pulse Shapes 65
(All values in microseconds) 65
Table 2-7: Field Index 70
Table 2-8: Flight Status Codes 78
Table 2-9: Settings of RAT, VRAT, and HRAT for the 18/24s Freeze Period 86
Table 2-10: Horizontal Sense Bits (HSB field) 95
Table 2-11: Vertical Sense Bits (VSB field) 97
Table 2-12: Capability Class (CC) Subfield in Aircraft Operational Status Messages, Airborne Format 110
Table 2-13: Operational Mode (OM) Subfield in Aircraft Operational Status Messages, Airborne Format 111
Table 2-14: Coordination Timing Requirements 118
Table 2-15: AGL Input Accuracy Requirements 136
Table 2-16: DAA Prioritized Track State Output Data 138
Table 2-17: Out-of-Band Rejection 142
Table 2-18: Illegal Altitude Codes 145
Table 2-19: Improvement Factors For Higher Resolution Whisper-Shout Sequences 149
Table 2-20: Surveillance Target Track Capacity 160
Table 2-21: Summary of Rules for Determining Air-Ground Status for Mode C (ATCRBS) Transponders 164
Table 2-22: Interval Between Revalidations 179
Table 2-23: Summary of STM Outputs for Nominal Intruder Surveillance Inputs 195
Table 2-24: Summary of STM Outputs for Bearingless Intruder Surveillance Inputs 196
Table 2-25: Summary of STM Outputs for NAR Intruder Surveillance Inputs 197
Table 2-26: Summary of ACAS Xu STM ADS-B Validation Scheme 200
Table 2-27: Barometric Altitude Observation - [ADD Table 18] 219
Table 2-28: Radio Altitude Observation – [ADD Table 19] 220
Table 2-29: Heading Observation – [ADD Table 20] 221
Table 2-30: WGS84 Observation - [ADD Table 21] 222
Table 2-31: Ownship Discretes - [ADD Table 17] 223
Table 2-32: DF0 Message - [ADD Table 9] 224
Table 2-33: Mode C Reply Message - [ADD Table 10] 226
Table 2-34: State Vector Position Report - [ADD Table 12] 229
Table 2-35: State Vector Velocity Report - [ADD Table 13] 230
Table 2-36: Mode Status Report - [ADD Table 14] 232
Table 2-37: UF16UDS30 Message - [ADD Table 22] 233
Table 2-38: Coordination Capability Report - [ADD Table 23] 234
Table 2-39: Xu ATAR Report Message – [ADD Table 16] 234
Table 2-40: State Vector UAT Report – [ADD Table 15] 236
Table 2-41: Target Designation 237
Table 2-42: STM/TRM Output Data Summary 238
Table 2-43: STM and TRM Output Interface Fields (superscripts next to particular fields correspond to notes below table) 239
Table 2-44: RTCA DO-365 Intruder Symbols for Combinations of Vertical and Horizontal Intruder Codes 242

Table 2-45: TRMAlertingData 243
Table 2-46: TRM Vertical RA Output Data (VTRMDisplayData) 243
Table 2-47: Vertical RWC Band Region Limits 245
Table 2-48: Horizontal RA and RWC Output Data (HTRMDisplayData) 246
Table 2-49: Horizontal RWC Band Region Limits 248
Table 2-50: Xu Codes 250
Table 2-51: StmDisplayStruct 251
Table 2-52: TRMIntruderDisplayData 252
Table 2-53: HTRMIntruderDisplayData 253
Table 2-54: Acceptable Minimum Combinations of Velocity Uncertainty and Ground Speed to Support Traffic Directionality 255
Table 2-55: TRMCoordinationInterrogationData 256
Table 2-56: Coordination Protocol 257
Table 2-57: XuTRMRABroadcastData 257
Table 2-58: CCCB 258
Table 2-59: XuTRMRWCBroadcastData 259
Table 2-60: TransponderData 260
Table 2-61: XuTRMGroundMsgData 261
Table 2-62: TRMIntruderDesignationData 262
Table 2-63: Mapping Resolution Advisories to Pilot and Ground Station Outputs and Displays - Vertical Advisories 264
Table 2-64: Mapping Resolution Advisories to Pilot and Ground Station Outputs and Displays - Horizontal Advisories 275
Table 2-65: STM Impact of Loss of Ownship GNSS and Heading 286
Table 2-66: Environmental Test Groupings 290
Table 2-67: Applicable Test Groups per Environmental Condition 293
Table 2-68: Standard Test Signal Pulse Shapes 296
Table 2-69: Standard Test Signal Total Jitter 297
Table 2-70: Confidence Factor Required For A 90% Confidence Level 323
Table 2-71: Minimum Number Of Trials Vs. Number Of Failures For The Required Probability Of Success Values Specified In §2.4.2.1.2 324
Table 2-72: Squitter And Reply Probability Vs. Range And Altitude 399
Table 2-73: Functional Areas Covered by Test Suite 415
Table 2-74: Input File Details 417
Table 2-75: STM Report Details 422
Table 2-76: TRM Report Details 425
Table 2-77: CostFile Details 430
Table 2-78: STM Report Test Values and Tolerances 437
Table 2-79: TRM Report Test Values and Tolerances 438
Table 2-80: Cost Value Tolerances 441
Table 2-81: Branches of Prescriptive Algorithms Not Exercised By Executing Prescriptive Test Encounters 442
Table 2-82: Unreachable Branches (Defensive Code) in Prescriptive Algorithms 443
Table 2-83: Unreachable Branches (Defensive Code) in Suggestive Algorithms 444
Table 2-84: ACAS Xu Spatial Correlation Test Cases 623
Table 2-85: Cross-Reference of Requirements to Associated Tests 629
Table 2-86: Cross-Reference of Associated Tests to Requirements 640
Table 3-1: Specification Of Total Altimetry System Performance 653
Table A-1: Code Pulse Agreement A-19
Table C-1: Percent Change in Select Metrics When Changing Update Rates to Reflect Surveillance Regions C-32
Table C-2: ADS-B Degradations (Worst-Case Scenarios are Shaded) C-36
Table C-3: Degraded Inputs Affecting Active Tracks (Worst-Case Scenarios are Shaded) C-38
Table C-4: Degraded Ownship Inputs (Worst-Case Scenarios are Shaded) C-39

Table D-1: Comparison of R and N for a Spherical Earth Radius as a Function of Latitude D-3
Table D-2: Example of Errors in Spherical Earth Approximation D-5
Table D-3: Example of Errors Using the Same N for Both Aircraft D-6
Table D - 4: Example of Errors in Ellipsoidal Differential Approximation with No Longitude Difference D-9
Table D-5: Example of Errors in Ellipsoidal Differential Approximation with No Latitude Difference D-10
Table D-6: Example of Errors in Ellipsoidal Differential Approximation with Combined Latitude, Longitude and Height Differences D-11
Table D-7: Example of Errors in Spherical Differential Approximation with No Longitude Difference .. D-13
Table D-8: Example of Errors in Spherical Differential Approximation with No Latitude Difference . D-14
Table D-9: Example of Errors in Spherical Differential Approximation with Combined Latitude, Longitude and Height Differences D-15
Table E-1: Error Sources in the Hybrid Slant Range Calculation and Validation with ACAS X Range . E-2
Table E – 2: Sample Allocation of Hybrid Data Processing Errors E-4
Table F-1 Test Group 10 ..... F-1
Table F-2: Test Group 20 ..... F-26
Table F-3: Test Group 30 ..... F-65
Table F-4: Test Group 40 ..... F-113
Table F-5: Test Group 50 ..... F-140
Table F-6: Test Group 60 ..... F-177
Table F-7: Test Group 70 ..... F-209
Table F-8: Test Group 99 ..... F-216
Table H–1: Simulated Reduction in 1090 MHz Receiver Occupancy H-7
Table I-1: ACAS Xu ATAR Input Interface I-2
Table I-2: Nominal ATAR Accuracy Parameters I-5
Table I-3: System-Level Acceptabiliy Limits for ACAS Xu ATAR Performance (Run 5.3) I-5
Table I-4: ACAS Xu ATAR Accuracy Requirements - Body-Aligned Spherical I-9
Table I-5: Ownship Attitude Accuracy Assumptions I-9
Table I-6: Simplest ACAS Xu Accuracy Requirement Translation I-10
Table I-7: ACAS Xu ATAR Tracker Lag Test Requirements I-6
Table I-8: Summary of ACAS Xu ATAR Track Requirements Test Encounter Sets I-8
Table I-9: Position Partial Derivatives - Full Derivation I-20
Table I-10: Velocity Partial Derivatives - Full Derivation I-21
Table I-11: Position Partial Derivatives – Zero Bank/Pitch I-24
Table I-12: Velocity Partial Derivatives – Zero Bank/Pitch I-25

This Page Intentionally Left Blank

1 PURPOSE AND SCOPE

1.1 Introduction

This document sets forth minimum operational performance standards for the Airborne Collision Avoidance System Xu (ACAS Xu) equipment, designed for platforms with a wide range of surveillance technologies and performance characteristics such as Unmanned Aircraft Systems (UAS).

Incorporated within these standards are system characteristics that should be of value to users, designers, manufacturers, and installers. These characteristics are intended to accommodate the requirements of various users.

1.1.1 Regulatory Context

Title 14 of the US Code of Federal Regulations (14 CFR), Part 91, §91.111(a), §91.113, and §91.181 require "out-the-window" on-board pilot actions to mitigate collision risk and avoid other traffic. UAS do not have an onboard pilot to comply with these rules, so they must find alternatives. Some UAS operators use waivers with chase planes and visual ground observers to comply, while others rely on airspace segregation or remote operations to mitigate traffic incursions. However, to enable non-segregated airspace use in the National Airspace System (NAS), UAS will need "see and avoid" strategies such as a Detect and Avoid (DAA) system. In the U.S., a DAA system enables the remote pilot to "see and avoid" all traffic using sensor and guidance technology. This includes both cooperative aircraft (those that carry equipment allowing ownship to receive state information about the intruder) and non-cooperative aircraft (those that are "silent" and all state data must be determined by sensors onboard the ownship).

A DAA system comprises a Remain Well Clear (RWC) function and a Collision Avoidance (CA) function. Some implementations might exclude one of these functions; the CA function is only required per applicable mandates based on aircraft operation and weight, and most UAS are currently not subject to these mandates (see §1.2.1.1). Although the RWC and CA functions share surveillance and tracking due to practical limitations of the platform, the two functions have distinct roles. RWC is defined as the ability to detect, analyze and maneuver to avoid potential conflicting traffic by applying adjustments to the current flight path in order to prevent the conflict from developing into a collision hazard. CA is defined as a last-resort method of preventing mid-air collisions between aircraft, as directed by a Collision Avoidance System (CAS).

For Instrument Flight Rules (IFR) operations, a remote pilot using a DAA system coordinates with Air Traffic Control (ATC) when receiving RWC alerts and may employ right-of-way rules per §91.113. When not in ATC contact, the pilot (when receiving an RWC alert) has the discretion to maneuver against other traffic. CA supplements ATC separation services, and is only used as a last resort if all other mitigations fail.

The RWC function provides alerting and guidance to ensure a UAS is DAA Well Clear (DWC) of surrounding traffic, while the CA function provides alerting and guidance to ensure that UAS operation does not pose a collision risk should other mitigations fail. These defined functions are found in RTCA DO-365, Minimum Operational Performance Standards (MOPS) for Detect and Avoid Systems (Ref. CC). DO-365 contains

