

RTCA, Inc.
1150 18th Street, NW, Suite 910
Washington, DC 20036-4001
USA

Minimum Operational Performance Standards (MOPS) For Airborne Weather Radar Systems

RTCA DO-220B
June 22, 2023

Prepared by: SC-230
© 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 230 (SC-230) and approved by the RTCA Program Management Committee (PMC) on June 22, 2023. It supersedes DO-220A with Change 1, dated August 17, 2018.

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 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 several 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

EXECUTIVE SUMMARY

Since the introduction of DO-220, there have been many technological advances in the field of airborne weather radar. DO-220A incorporated updates and corrections to the previous version. In addition to modernizing the requirements and test procedures for the weather, ground mapping, and forward-looking windshear functions set out in its predecessors, SC-230 added specifications for radar detection of turbulence and atmospheric threat awareness. DO-220B adds requirements and test procedures for a high-altitude ice crystal detection function. Any of these functions may be implemented individually or in combination with any others. This document has been designed such that the requirements and test procedures for each function are grouped into distinct sections to facilitate testing and showing of compliance.

This Page Intentionally Left Blank

TABLE OF CONTENTS

1	PURPOSE AND SCOPE	1
1.1	Introduction.....	1
1.2	System Overview	2
1.3	Intended Function	2
1.4	Operational Applications and Goals	3
1.4.1	Weather Detection	4
1.4.2	Ground Mapping.....	4
1.4.3	Forward-Looking Windshear Detection	4
1.4.4	Forward-Looking Turbulence Detection	4
1.4.5	Atmospheric Threat Awareness	4
1.4.6	High-Altitude Ice Crystal Detection	5
1.5	Assumptions.....	5
1.6	Test Procedures.....	5
1.7	Definition of Terms.....	6
1.8	Acronyms, Abbreviations, and Initialisms.....	6
1.9	References.....	8
1.9.1	General.....	8
1.9.2	Forward-Looking Windshear Detection	8
1.9.3	Forward-Looking Turbulence Detection	9
1.9.4	High-Altitude Ice Crystal Detection	10
2	EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES	11
2.1	General Requirements.....	11
2.1.1	Airworthiness.....	11
2.1.2	Intended Function	11
2.1.3	Federal Communications Commission Rules	11
2.1.4	Fire Protection.....	11
2.1.5	Operation of Controls	11
2.1.6	Accessibility of Controls.....	11
2.1.7	Radome Design.....	11
2.1.8	Equipment Interface Tolerances	12
2.1.9	Heading vs. Track Frame of Reference Discussion	12
2.1.10	Effects of Test.....	12
2.1.11	Design Assurance.....	12
2.1.12	Understandability of Displayed Information	12
2.1.13	Non-Interference	12
2.2	Equipment Performance – Standard Conditions.....	13
2.2.1	General Equipment Characteristics.....	13
2.2.2	Airborne Weather and Ground Mapping Radar Requirements.....	15
2.2.3	Forward-Looking Windshear Requirements.....	19
2.2.4	Forward-Looking Turbulence Detection Requirements	26
2.2.5	Atmospheric Threat Awareness	27
2.2.6	High-Altitude Ice Crystal Detection	28
2.3	Equipment Performance – Environmental Conditions	33
2.3.1	Environmental Test Conditions	33
2.4	Equipment Test Procedures	36
2.4.1	Definitions of Terms and Conditions of Test.....	36
2.4.2	Required Test Equipment.....	36
2.4.3	Detailed Test Procedures	37

2.4.4	Flight Evaluation Activities	60
3	MANUFACTURER CONSIDERATIONS FOR INSTALLED EQUIPMENT.....	63
3.1	Equipment Installation	63
3.1.1	Accessibility.....	63
3.1.2	Aircraft Environment (Subsection 2.3).....	63
3.1.3	Failure Protection.....	63
3.1.4	Interference Effects.....	63
3.1.5	Inadvertent Turnoff.....	63
3.1.6	Aircraft Power Source.....	63
3.1.7	Safety Precautions.....	64
3.1.8	Adjustment of Equipment (Paragraph 2.1.8)	64
3.1.9	Warm-up Period.....	64
3.2	Installed Equipment Performance Considerations	64
3.2.1	Weather Radar Transmission Loss	64
3.2.2	System Performance (Subparagraphs 2.2.2.9 and 2.2.3.3)	64
3.2.3	Aperture Blockage	64
3.3	Test Procedures for Installed Equipment Performance.....	65
3.3.1	Conformity Inspection	65
3.3.2	Ground Test Procedure	65
3.3.3	Flight Test Procedures	66
4	AIRCRAFT OPERATIONAL PERFORMANCE CHARACTERISTICS.....	69
4.1	Radome Maintenance Requirements	69
5	MEMBERSHIP.....	71
APPENDIX A	FORWARD-LOOKING WINDSHEAR TEST CASES	A-1
A.1	General Windshear Scenario Test Information.....	A-1
A.2	Considerations Associated with the Use of The Windshear Test Set-Up	A-1
A.3	Windshear Scenarios.....	A-8
APPENDIX B	PLOTS FOR FORWARD-LOOKING WINDSHEAR DATA SETS.....	B-1
B.1	Input Sounding Plotted on Skew T-log p Diagrams.....	B-1
B.2	North-South and East-West FBAR Contour Plots	B-8
B.3	Radar Reflectivity Contour Plots	B-23
B.4	Wind Vectors.....	B-28
B.5	Along-Path Flight Scenario Plots	B-37
APPENDIX C	ANALYTICAL TECHNIQUE FOR EVALUATION OF MISSED EVENTS & NUISANCE ALERTS.....	C-1
C.1	Introduction	C-1
C.2	Single Pulse SNR	C-1
C.3	Velocity Measurement Error.....	C-2
C.4	Errors in Hazard Factor Estimation Using the Least-Squares Algorithm	C-2
C.5	Errors in Averaging the Hazard Factor Estimates Along an Azimuth Line	C-2
C.6	Averaging Over Adjacent Azimuth Lines	C-4
C.7	Missed Detection and Detection Probability (Single Scan)	C-4
C.8	Nuisance Alert Probability	C-4

C.9	Multiple Pixel Detection Requirements	C-5
C.10	Requirement for Hazard Detection on More Than One Azimuth Scan	C-6
C.11	Cumulative Probability of Detection and Nuisance Alert	C-6
C.12	Calculations.....	C-7
C.13	Summary and Conclusions	C-8
C.14	Figures.....	C-9
APPENDIX D HIGH-ALTITUDE ICE CRYSTAL DETECTION TEST CASES.....		D-1
D.1	Statistical Evaluation of Performance	D-1
D.2	Simulated Evaluation of Performance	D-1
APPENDIX E HISTORICAL INFORMATION AND DERIVATIONS		E-1
E.1	Performance Index Equation Derivation	E-1
E.2	Conversion Calculations.....	E-5

TABLE OF TABLES

Table 1-1: Airborne Weather Radar Equipment Classes and Applicable Minimum Performance Standards.....	3
Table 2-1: K Factors and Two-way Attenuation Values	17
Table 2-2: Minimum Performance Index vs. Maximum System Range.....	18
Table 2-3: Windshear Alerts	23
Table 2-4: Aircraft Class and Minimum Performance Level.....	26
Table 2-5: Equipment Level (Minimum Operational Range).....	30
Table 2-6: High-Altitude Ice Crystal Symbology.....	31
Table 2-7: Performance Test Requirements for Environmental Tests.....	34
Table D-1: Description of variables for each TASS weather model case.....	D-4
Table D-2: Summary of all event scenarios.....	D-6
Table E-1: Conversion λ^2 to nautical miles.....	E-6
Table E-2: Avoidance and Penetration Calculations	E-7
Table E-3: Actual Installation Losses Differ, Lost Adjustments	E-8
Table E-4: Avoidance Vs. Penetration.....	E-8
Table E-5: Conversion to Db Format.....	E-8
Table E-6: K Value Calculations	E-9
Table E-7: K Factor	E-9
Table E-8: Equivalent PIs for New Calculation Method	E-10

TABLE OF FIGURES

Figure 2-1: Windshear Alert Regions	22
Figure 2-2: Windshear System Icon Examples.....	25
Figure 2-3: Example Symbology for High and Moderate IWC.....	32
Figure 2-4: Alternate Symbology for High and Moderate IWC	32
Figure 2-5: Indicated Range Error Test Configuration	39
Figure 2-6: Minimum Displayed Target Range Test Configuration.....	40
Figure 2-7: Windshear Test Configuration	48
Figure 2-8: System Simulation Methodology	54
Figure A-1: Formation of Combined Clutter and Rain Return	A-4
Figure A-2: Generation of Microburst Radar Return Data	A-5
Figure B-1: Skew-T Diagram of Atmospheric Sounding for Data Set #1	B-1

Figure B-2: Skew-T Diagram of Atmospheric Sounding for Data Set #2	B-2
Figure B-3: Skew-T Diagram of Atmospheric Sounding for Data Set #3	B-3
Figure B-4: Skew-T Diagram of Atmospheric Sounding for Data Set #4	B-4
Figure B-5: Skew-T Diagram of Atmospheric Sounding for Data Set #5	B-5
Figure B-6: Skew-T Diagram of Atmospheric Sounding for Data Set #6	B-6
Figure B-7: Skew-T Diagram of Atmospheric Sounding for Data Set #7	B-7
Figure B-8: Data Set/Time #111: East-West FBAR at 300 Meters Elevation.....	B-8
Figure B-9: Data Set/Time #111: East-West FBAR at 50 Meters Elevation.....	B-8
Figure B-10: Data Set/Time #237: North-South FBAR at 300 Meters Elevation	B-9
Figure B-11: Data Set/Time #237: North-South FBAR at 50 Meters Elevation	B-9
Figure B-12: Data Set/Time #237: East-West FBAR at 300 Meters Elevation.....	B-10
Figure B-13: Data Set/Time #237: East-West FBAR at 50 Meters Elevation.....	B-10
Figure B-14: Data Set/Time #349: North-South FBAR at 300 Meters Elevation	B-11
Figure B-15: Data Set/Time #349: North-South FBAR at 50 Meters Elevation	B-11
Figure B-16: Data Set/Time #349: East-West FBAR at 300 Meters Elevation.....	B-12
Figure B-17: Data Set/Time #349: East-West FBAR at 50 Meters Elevation.....	B-12
Figure B-18: Data Set/Time #351: North-South FBAR at 300 Meters Elevation	B-13
Figure B-19: Data Set/Time #351: North-South FBAR at 50 Meters Elevation	B-13
Figure B-20: Data Set/Time #351: East-West FBAR at 300 Meters Elevation.....	B-14
Figure B-21: Data Set/Time #351: East-West FBAR at 50 Meters Elevation.....	B-14
Figure B-22: Data Set/Time #436: East-West FBAR at 300 Meters Elevation.....	B-15
Figure B-23: Data Set/Time #436: East-West FBAR at 50 Meters Elevation.....	B-15
Figure B-24: Data Set/Time #540: North-South FBAR at 300 Meters Elevation	B-16
Figure B-25: Data Set/Time #540: North-South FBAR at 50 Meters Elevation	B-16
Figure B-26: Data Set/Time #540: East-West FBAR at 300 Meters Elevation.....	B-17
Figure B-27: Data Set/Time #540: East-West FBAR at 50 Meters Elevation.....	B-17
Figure B-28: Data Set/Time #545: North-South FBAR at 300 Meters Elevation	B-18
Figure B-29: Data Set/Time #545: North-South FBAR at 50 Meters Elevation	B-18
Figure B-30: Data Set/Time #545: East-West FBAR at 300 Meters Elevation.....	B-19
Figure B-31: Data Set/Time #545: East-West FBAR at 50 Meters Elevation.....	B-19
Figure B-32: Data Set/Time #614: North-South FBAR at 300 Meters Elevation	B-20
Figure B-33: Data Set/Time #614: North-South FBAR at 50 Meters Elevation	B-20
Figure B-34: Data Set/Time #614: East-West FBAR at 300 Meters Elevation.....	B-21
Figure B-35: Data Set/Time #614: East-West FBAR at 50 Meters Elevation.....	B-21
Figure B-36: Data Set/Time #727: East-West FBAR at 300 Meters Elevation.....	B-22
Figure B-37: Data Set/Time #727: East-West FBAR at 50 Meters Elevation.....	B-22
Figure B-38: Data Set/Time #111: Radar Reflectivity	B-23
Figure B-39: Data Set/Time #237: Radar Reflectivity	B-23
Figure B-40: Data Set/Time #349: Radar Reflectivity	B-24
Figure B-41: Data Set/Time #351: Radar Reflectivity	B-24
Figure B-42: Data Set/Time #436: Radar Reflectivity	B-25
Figure B-43: Data Set/Time #540: Radar Reflectivity	B-25
Figure B-44: Data Set/Time #545: Radar Reflectivity	B-26
Figure B-45: Data Set/Time #614: Radar Reflectivity	B-26
Figure B-46: Data Set/Time #727: Radar Reflectivity	B-27
Figure B-47: Data Set/Time #111: Horizontal Wind Vectors at 50 Meters Elevation	B-28
Figure B-48: Data Set/Time #111: East-West Vertical Wind Vectors at $y = 0$ Km	B-28
Figure B-49: Data Set/Time #237: Horizontal Wind Vectors at 50 Meters Elevation	B-29
Figure B-50: Data Set/Time #237: East-West Vertical Wind Vectors at $y = -1.38$ Km.....	B-29
Figure B-51: Data Set/Time #349: Horizontal Wind Vectors at 50 Meters Elevation	B-30
Figure B-52: Data Set/Time #349: North-South Vertical Wind Vectors at $x = 8.49$ Km.....	B-30
Figure B-53: Data Set/Time #351: Horizontal Wind Vectors at 50 Meters Elevation	B-31
Figure B-54: Data Set/Time #351: East-West Vertical Wind Vectors at $y = -5.07$ Km.....	B-31
Figure B-55: Data Set/Time #436: Horizontal Wind Vectors at 50 Meters Elevation	B-32

Figure B-56: Data Set/Time #436: East-West Vertical Wind Vectors at y = 0 Km	B-32
Figure B-57: Data Set/Time #540: Horizontal Wind Vectors at 50 Meters Elevation	B-33
Figure B-58: Data Set/Time #540: North-South Vertical Wind Vectors at x = 3.79 Km.....	B-33
Figure B-59: Data Set/Time #545: Horizontal Wind Vectors at 50 Meters Elevation	B-34
Figure B-60: Data Set/Time #545: North-South Vertical Wind Vectors at x = 4.262 Km.....	B-34
Figure B-61: Data Set/Time #614: Horizontal Wind Vectors at 50 Meters Elevation	B-35
Figure B-62: Data Set/Time #614: North-South Vertical Wind Vectors at x = 14.471 Km.....	B-35
Figure B-63: Data Set/Time #727: Horizontal Wind Vectors at 50 Meters Elevation	B-36
Figure B-64: Data Set/Time #727: East-West Vertical Wind Vectors at y = 1.0 Km	B-36
Figure B-65: FLWS Scenario 1: Data Set/Time #111, Aligned for Takeoff on Track 90.....	B-37
Figure B-66: FLWS Scenario 2: Data Set/Time #111, Straight-In Approach on Track 90	B-37
Figure B-67: FLWS Scenario 3: Data Set/Time #237, Straight-In Approach on Track 180.....	B-38
Figure B-68: FLWS Scenario 4: Data Set/Time #237, Straight-In Approach on Track 90, Below Alert Threshold Shear	B-38
Figure B-69: FLWS Scenario 5: Data Set/Time #237, Go-Around on Track 270.....	B-39
Figure B-70: FLWS Scenario 6: Data Set/Time #349, Straight-In Approach on Track 90, Below Alert Threshold Shear	B-39
Figure B-71: FLWS Scenario 7: Data Set/Time #349, Straight-In Approach on Track 360.....	B-40
Figure B-72: FLWS Scenario 8: Data Set/Time #351, Aligned for Takeoff on Track 360.....	B-40
Figure B-73: FLWS Scenario 9: Data Set/Time #351, Aligned for Takeoff on Track 90.....	B-41
Figure B-74: FLWS Scenario 10: Data Set/Time #351, Takeoff Gear-Up Height on Track 90.....	B-41
Figure B-75: FLWS Scenario 11: Data Set/Time #351, Straight-In Approach on Track 360.....	B-42
Figure B-76: FLWS Scenario 12: Data Set/Time #351, Straight-In Approach on Track 45.....	B-42
Figure B-77: FLWS Scenario 13: Data Set/Time #351, Straight-In Approach on Track 90.....	B-43
Figure B-78: FLWS Scenario 14: Data Set/Time #351, Straight-In Approach on Track 135.....	B-43
Figure B-79: FLWS Scenario 15: Data Set/Time #351, Straight-In Approach on Track 270.....	B-44
Figure B-80: FLWS Scenario 16: Data Set/Time #351, Straight-In Approach on Track 315, Two Windshears on This Path	B-44
Figure B-81: FLWS Scenario 17 (Right Turn): Data Set/Time #351, Curved Approach Right Turn with Localizer on Track 90.....	B-45
Figure B-82: FLWS Scenario 17 (Left Turn): Data Set/Time #351, Curved Approach Left Turn with Localizer on Track 90.....	B-45
Figure B-83: FLWS Scenario 18: Data Set/Time #436, Aligned for Takeoff on Track 90.....	B-46
Figure B-84: FLWS Scenario 19: Data Set/Time #436, Straight-In Approach on Track 90.....	B-46
Figure B-85: FLWS Scenario 20: Data Set/Time #436, Worst-Case Drift Angle Approach on Track 90	B-47
Figure B-86: FLWS Scenario 21: Data Set/Time #540, Takeoff Gear-Up Height on Track 270-	B-47
Figure B-87: FLWS Scenario 22: Data Set/Time #540, Straight-In Approach on Track 360.....	B-48
Figure B-88: FLWS Scenario 23: Data Set/Time #540, Worst-Case Drift Angle Approach on Track 360	B-48
Figure B-89: FLWS Scenario 24: Data Set/Time #540, Go-Around on Track 360.....	B-49
Figure B-90: FLWS Scenario 25 (Right Turn): Data Set/Time #540, Curved Approach Right Turn with Localizer on Track 270.....	B-49
Figure B-91: FLWS Scenario 25 (Left Turn): Data Set/Time #540, Curved Approach Left Turn with Localizer on Track 270.....	B-50
Figure B-92: FLWS Scenario 26: Data Set/Time #545, Straight-In Approach on Track 360.....	B-50
Figure B-93: FLWS Scenario 27 (Right Turn): Data Set/Time #614, Curved Approach Right Turn with Localizer on Track 180.....	B-51
Figure B-94: FLWS Scenario 27 (Left Turn): Data Set/Time #614, Curved Approach Left Turn with Localizer on Track 180.....	B-51
Figure B-95: FLWS Scenario 28: Data Set/Time #614, Straight-In Approach on Track 360.....	B-52
Figure B-96: FLWS Scenario 29: Data Set/Time #614, Straight-In Approach on Track 45.....	B-52
Figure B-97: FLWS Scenario 30: Data Set/Time #614, Straight-In Approach on Track 90.....	B-53
Figure B-98: FLWS Scenario 31: Data Set/Time #614, Straight-In Approach on Track 180.....	B-53

Figure B-99: FLWS Scenario 32: Data Set/Time #614, Straight-In Approach on Track 225	B-54
Figure B-100: FLWS Scenario 33: Data Set/Time #614, Straight-In Approach on Track 270	B-54
Figure B-101: FLWS Scenario 34: Data Set/Time #614, Straight-In Approach on Track 315	B-55
Figure B-102: FLWS Scenario 35: Data Set/Time #727, Aligned for Takeoff on Track 270	B-55
Figure B-103: FLWS Scenario 36: Data Set/Time #727, Straight-In Approach on Track 270	B-56
Figure C-1: List of Parameters for Calculation of Detection and Nuisance Alert Probabilities Shown in Subsequent Figures.	C-9
Figure C-2: Radar Single Pulse Signal-To-Noise Ratio versus Radar Range for Three Values of Rain Reflectivity.	C-10
Figure C-3: Standard Deviation of a Velocity Measurement Based on FFT Processing of 128 Pulses. The Weather Spectral Width = 3 m/s.	C-10
Figure C-4: Standard Deviation of 1000 Meter Averaged F-Factor (or FBAR) Using FFT Processing of 128 Samples. No Averaging Over Adjacent Azimuth Lines Is Used.	C-11
Figure C-5: Sketch Indicating the Technique for Calculation of Detection and Nuisance Alert Probability: Must-Alert F-Factor = 0.13 And Must-Not-Alert F-Factor = 0.085.	C-11
Figure C-6: The Probability of a Missed Detection of a 0.13 Averaged Hazard Plotted versus Range.	C-12
Figure C-7: The Probability of a Nuisance Detection of a 0.085 Averaged Hazard Plotted versus Range.	C-12
Figure C-8: Detection and Nuisance Alert Probability Plotted versus The Single Pulse Signal-To- Noise Ratio.	C-13
Figure C-9: Ratio of Detection to Nuisance Alert Probability Plotted versus Single Pulse Signal- To-Noise Ratio.....	C-13
Figure C-10: Ratio Plot Similar to Figure C-9, Except That the Post-Processed Signal-To-Noise Ratio Is Used as The Ordinate. Use A Signal-To-Noise Ratio Threshold of Approximately 7.5 dB To Maintain the Ratio of One Nuisance Alert Per 10 True Alerts.....	C-14
Figure C-11: Cumulative Probability of Missed and Nuisance Detection For -5 dBZ Weather Reflectivity and an SNR Threshold Of -3 dB.	C-14
Figure C-12: Cumulative Probability of Missed and Nuisance Detection For 0 dBZ Weather Reflectivity and an SNR Threshold Of -3 dB.	C-15
Figure C-13: Cumulative Probability of Missed and Nuisance Detection For +5 dBZ Weather Reflectivity and an SNR Threshold Of -3 dB.	C-15
Figure C-14: Probability of a Missed Detection of a .13 Hazard for the NASA System Using a Hazard Area Threshold Of 0.2 Sq. Km. and Requiring Two Consecutive Scans Prior To Declaring an Alert.	C-16
Figure C-15: Probability of a Nuisance Detection of a 0.085 Hazard for the NASA System Using a Hazard Area Threshold Of 0.2 Sq. Km. and Requiring Two Consecutive Scans Prior To Declaring an Alert.	C-16
Figure C-16: Cumulative Probability of a Missed and Nuisance Detection for the NASA System with an SNR Threshold Of -3 dB and a Weather Reflectivity of -5 dBZ.....	C-17
Figure C-17: Cumulative Probability of a Missed and Nuisance Detection for the NASA System with an SNR Threshold of -3 dB and a Weather Reflectivity of 0 dBZ.	C-17
Figure C-18: Cumulative Probability of a Missed and Nuisance Detection for the NASA System with an SNR Threshold of -3 dB and a Weather Reflectivity of +5 dBZ.....	C-18
Figure D-1: Ice Crystal Detection System Simulation Methodology	D-2
Figure D-2: Scenario 1: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-9
Figure D-3: Scenario 1: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-9

Figure D-4: Scenario 1: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-10
Figure D-5: Scenario 1: IWC at the aircraft altitude with a three nautical mile averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-10
Figure D-6: Scenario 1: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three nautical mile averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black ‘X’ indicates the target location.	D-11
Figure D-7: Scenario 1: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black ‘X’ indicate the target location.	D-12
Figure D-8: Scenario 2: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-14
Figure D-9: Scenario 2: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-14
Figure D-10: Scenario 2: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-15
Figure D-11: Scenario 2: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-15
Figure D-12: Scenario 2: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black ‘X’ indicates the target location.	D-16
Figure D-13: Scenario 2: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black ‘X’ indicate the target location.	D-17
Figure D-14: Scenario 3: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-19
Figure D-15: Scenario 3: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-19
Figure D-16: Scenario 3: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-20
Figure D-17: Scenario 3: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-20
Figure D-18: Scenario 3: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black ‘X’ indicates the target location.	D-21
Figure D-19: Scenario 3: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black ‘X’ indicate the target location.	D-22

Figure D-20: Scenario 4: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-24
Figure D-21: Scenario 4: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-24
Figure D-22: Scenario 4: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-25
Figure D-23: Scenario 4: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-25
Figure D-24: Scenario 4: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black 'X' indicates the target location.	D-26
Figure D-25: Scenario 4: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black 'X' indicate the target location.	D-27
Figure D-26: Scenario 5: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-29
Figure D-27: Scenario 5: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-29
Figure D-28: Scenario 5: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-30
Figure D-29: Scenario 5: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-30
Figure D-30: Scenario 5: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black 'X' indicates the target location.	D-31
Figure D-31: Scenario 5: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black 'X' indicate the target location.	D-32
Figure D-32: Scenario 6: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-34
Figure D-33: Scenario 6: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-34
Figure D-34: Scenario 6: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-35
Figure D-35: Scenario 6: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-35
Figure D-36: : Scenario 6: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication	

criteria. The black arrow denotes the aircraft altitude and flight direction and the black 'X' indicates the target location.	D-36
Figure D-37: Scenario 6: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black 'X' indicate the target location.	D-37
Figure D-38: Scenario 7: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-39
Figure D-39: Scenario 7: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-39
Figure D-40: Scenario 7: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-40
Figure D-41: Scenario 7: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-40
Figure D-42: Scenario 7: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black 'X' indicates the target location.	D-41
Figure D-43: Scenario 7: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black 'X' indicate the target location.	D-42
Figure D-44: Scenario 8: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-44
Figure D-45: Scenario 8: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-44
Figure D-46: Scenario 8: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-45
Figure D-47: Scenario 8: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-45
Figure D-48: Scenario 8: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black 'X' indicates the target location.	D-46
Figure D-49: Scenario 8: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black 'X' indicate the target location.	D-47
Figure D-50: Scenario 9: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-49
Figure D-51: Scenario 9: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-49
Figure D-52: Scenario 9: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-50
Figure D-53: Scenario 9: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-50

Figure D-54: Scenario 9: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black 'X' indicates the target location.	D-51
Figure D-55: Scenario 9: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black 'X' indicate the target location.	D-52
Figure D-56: Scenario 10: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-54
Figure D-57: Scenario 10: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-54
Figure D-58: Scenario 10: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-55
Figure D-59: Scenario 10: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-55
Figure D-60: Scenario 10: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black 'X' indicates the target location.	D-56
Figure D-61: Scenario 10: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black 'X' indicate the target location.	D-57
Figure D-62: Scenario 11: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-59
Figure D-63: Scenario 11: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-59
Figure D-64: Scenario 11: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-60
Figure D-65: Scenario 11: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-60
Figure D-66: Scenario 11: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black 'X' indicates the target location.	D-61
Figure D-67: Scenario 11: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black 'X' indicate the target location.	D-62
Figure D-68: Scenario 12: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-64
Figure D-69: Scenario 12: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.....	D-64
Figure D-70: Scenario 12: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black 'X' indicates the target location.	D-65

Figure D-71: Scenario 12: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-65
Figure D-72: Scenario 12: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black ‘X’ indicates the target location.	D-66
Figure D-73: Scenario 12: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black ‘X’ indicate the target location.	D-67
Figure D-74: Scenario 13: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.....	D-69
Figure D-75: Scenario 13: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.....	D-69
Figure D-76: Scenario 13: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-70
Figure D-77: Scenario 13: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-70
Figure D-78: Scenario 13: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black ‘X’ indicates the target location.	D-71
Figure D-79: Scenario 13: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black ‘X’ indicate the target location.	D-72
Figure D-80: Scenario 14: Simulated reflectivity (i.e., RRF variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.....	D-74
Figure D-81: Scenario 14: IWC (i.e., PRCP variable) at the aircraft altitude. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.....	D-74
Figure D-82: Scenario 14: IWC at the aircraft altitude binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-75
Figure D-83: Scenario 14: IWC at the aircraft altitude with a three-NMI averaging filter applied in the direction of the aircraft flight track binned according to indication criteria thresholds. The black arrow denotes the aircraft flight path and the black ‘X’ indicates the target location.	D-75
Figure D-84: Scenario 14: The vertical cross sections of a) simulated reflectivity, b) IWC, c) IWC binned according to indication criteria, and d) IWC with a three-NMI averaging filter applied in the direction of the air flight track binned according to indication criteria. The black arrow denotes the aircraft altitude and flight direction and the black ‘X’ indicates the target location.	D-76
Figure D-85: Scenario 14: IWC and three-NMI-averaged IWC along the flight track at the aircraft altitude. The dashed black line and black ‘X’ indicate the target location.	D-77
Figure E-1: Target Pulse Volume	E-4

This Page Intentionally Left Blank

1 PURPOSE AND SCOPE

1.1 Introduction

This document contains Minimum Operational Performance Standards for Airborne Radar Systems that may include any combination of the following functions: weather detection, ground mapping, forward-looking windshear detection, forward-looking turbulence detection, atmospheric threat awareness capability, or high-altitude ice crystal detection.

These standards specify system characteristics that should be useful to designers, manufacturers, installers, and users of the equipment. The requirements defined in Subsection 2.1 and Paragraphs 2.2.1, 0, 2.2.5, and 0 of this MOPS are applicable to both rotorcraft and fixed-wing aircraft. Paragraph 2.2.5 can be used to address the indication of turbulent conditions or microburst events ahead of the aircraft for rotorcraft. This document does not directly define the MOPS for forward-looking windshear or turbulence detection capability for rotorcraft.

Compliance with these standards is one means of assuring that the equipment will perform its intended function(s) satisfactorily under all conditions normally encountered in routine aeronautical operation. Any regulatory application of this document is the sole responsibility of appropriate governmental agencies.

Section 1 of this document provides information needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment operations and operational goals, as envisioned by the members of Special Committee 230, and establishes the basis for the standards stated in Sections 2 and 3. This section also contains definitions and assumptions essential to proper understanding of this document.

Section 2 contains the Minimum Performance Standards for the equipment. These standards specify the required performance under standard environmental conditions. Also included are recommended test procedures necessary to demonstrate equipment compliance with the stated minimum requirements.

Section 3 describes the performance required of installed equipment. Tests for the installed equipment are included when performance cannot be adequately determined otherwise.

Section 4 describes the operational performance characteristics for equipment installations and defines conditions that will assure the equipment user that the expected operational environment will allow safe and reliable operation of the equipment.

Appendix A, a normative appendix, describes the windshear database developed for the certification testing of airborne forward-looking windshear detection systems, and defines the test scenarios used for this testing. It also includes considerations associated with the use of the windshear test set-up

Appendix B, an informative appendix, includes plots associated with the windshear data sets.

Appendix C, a normative appendix, describes the analytical technique for evaluation of windshear missed events and nuisance alerts.

Appendix D, a normative appendix, describes the atmospheric database developed for the certification testing of airborne forward-looking ice crystal detection systems, and defines the test scenarios used for this testing.

Appendix E, an informative appendix, contains historical information and derivations that may be useful to the radar designer.