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 with Errata
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Prepared by: SC-230
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RTCA, Inc.

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

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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. Errata inclusion was prepared by RTCA Secretariat, and the content reviewed by the RTCA PMC on June 27, 2024. This errata version corrects publication errors in the initial publication.

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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.

The following items are integrated into this release to correct publication errors in the initial publication:

- Page 1, Section 1.1, second paragraph, third line, corrected display of links for 2.2.2 and 2.2.6
- Page 5, Section 1.6, under Environmental Tests, first paragraph, first line, corrected display of link for 2.3
- Page 18, Table 2-2, Note 5, corrected display of link for Appendix E.1 vs D.2
- Page 43, Section 2.4.3.1.3.5, corrected link for Windshear test procedures see subparagraph 2.4.3.3
- Page 43, Section 2.4.3.2, corrected display link for 2.2.2
- Page 45, Section 2.4.3.2.6, under Measurement Procedures for electronically steerable antennas, corrected display link for 2.3
- Page 48, Section 2.4.3.3.3, under Measurement Procedure, corrected display link for Figure 2-7 vs 2-5
- Page 63, Section 3.1.2, corrected display link for Subsection 2.3
- Page D-4, Section D.2.1, second paragraph, last line, corrected display link for D.2.4
- Page D-6, Section D.2.4.3, first paragraph, third line, corrected display link for D.2.4
- Page D-6, Section D.2.4.3, last paragraph, second line, corrected display link for D.2.4
- Page D-7, Section D.2.4.4, first paragraph, first line, corrected display link for D.2.4

No other content or technical content was changed.

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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, 2.2.2, 2.2.5, and 2.2.6 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.

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The word “equipment” as used herein includes all components or units necessary (as determined by the equipment manufacturer or installer) for the equipment to properly perform its function. For example, the airborne radar "equipment" may include a radome, an antenna, antenna mounting, transmission line, a receiver/transmitter unit, a control/display unit, shock mounts, etc. In this illustrative example, all these components or units comprise the "equipment.” It should not be inferred from the example that every equipment configuration will necessarily include (or be limited to) all these components or units. This will depend on the design chosen by the equipment manufacturer and the techniques of the installer.

Throughout this document, refer to the latest available revision of all reference material unless otherwise specified.

1.2 System Overview

A weather radar system is equipment that actively senses both meteorological and non-meteorological targets, depending on the operational mode. A weather radar system can be a valuable tool to help the flight crew make informed decisions and potentially avoid hazardous situations due to heavy/extreme precipitation, windshear, turbulence, high-altitude ice crystals, or other atmospheric threats. The radar system may include various combinations of components such as a control panel, antenna mounting, antenna, display, receiver/transmitter, and associated software. Note that either the equipment manufacturer or another entity (e.g., integrator) may provide the controller.

Radar installations may include a dedicated display or may share a display with other aircraft systems. Most radar installations will share a multipurpose display such as an Electronic Flight Instrument System. For airborne radar systems with this architecture, the display requirements set forth in this document apply to the shared display device when used for displaying radar information.

1.3 Intended Function

The intended functions of the weather radar system described in this document fall into six general categories.

- Weather Detection
- Ground Mapping
- Forward-Looking Windshear Detection (may also be referred to as FLWS Detection, Predictive Windshear, or PWS)
- Forward-Looking Turbulence Detection
- Atmospheric Threat Awareness
- High-Altitude Ice Crystal Detection

The radar system manufacturer may choose to implement equipment providing these capabilities in any combination. If the system provides multiple functions simultaneously, for instance weather detection and forward-looking windshear detection, then the minimum performance standards for each function should be met at all times.

The standards prescribed in this MOPS are thus grouped according to the corresponding intended function such that they can be applied to the functions implemented in the equipment.

U.S. Title 14 Code of Federal Regulations (14 CFR) or European Aviation Safety Agency (EASA) Certification Specification (CS) Sections 23.2500, 23.2510, 23.2605, 25.1309, 27.1309, and 29.1309 specify design requirements based on functional hazard

categorizations. The latest revisions of Advisory Circulars AC 23.1309-1 (or other acceptable means of compliance), 25.1309-1, AC 27-1, and AC 29-2 provide a basis for evaluation of the effects of the loss or malfunction of these functions.

Note: The effect of loss or malfunction should be considered at the aircraft level and at the equipment level as it may contribute to the aircraft level effect.

Table 1-1 defines the equipment class and applicable minimum performance standards for each intended function.

Table 1-1: Airborne Weather Radar Equipment Classes and Applicable Minimum Performance Standards

Equipment Class	Equipment Type	Minimum Performance Standards
A	Forward-Looking Windshear Detection Capability	RTCA DO-220B, section 2.2, with the following exclusions: paragraphs 2.2.1.3.6, 2.2.1.3.7, 2.2.1.3.8, 2.2.2, 2.2.4, 2.2.5 and 2.2.6.
B	Forward-Looking Turbulence Detection Capability	RTCA DO-220B, section 2.2, with the following exclusions: paragraphs 2.2.1.3.5, 2.2.1.3.7, 2.2.1.3.8, 2.2.2, 2.2.3, 2.2.5 and 2.2.6.
C	Airborne Weather and Ground Mapping Radar	RTCA DO-220B, section 2.2, with the following exclusions: paragraphs 2.2.1.3.5, 2.2.1.3.6, 2.2.1.3.7, 2.2.1.3.8, 2.2.3, 2.2.4, 2.2.5 and 2.2.6.
D	Atmospheric Threat Awareness Capability	RTCA DO-220B, section 2.2, with the following exclusions: paragraphs 2.2.1.3.5, 2.2.1.3.6, 2.2.1.3.8, 2.2.2, 2.2.3, 2.2.4, and 2.2.6.
E1, E2, or E3	High-Altitude Ice Crystal Detection Capability	RTCA DO-220B, section 2.2, with the following exclusions: paragraphs 2.2.1.3.5, 2.2.1.3.6, 2.2.1.3.7, 2.2.2, 2.2.3, 2.2.4 and 2.2.5. The number associated with this Equipment Class refers to the Equipment Level as defined in Subparagraph 2.2.6.4.

1.4 Operational Applications and Goals

These applications pertain to both transport aircraft and general aviation aircraft. These requirements may also provide guidance for Unmanned Aircraft Systems (UAS). The applications and goals of the Airborne Radar System include one or more of the following:

- Provide timely indications of weather conditions to aid in avoiding hazardous weather and to help with in-flight route planning.
- Provide the capability to maintain contact with geographic features such as international shoreline boundaries as a supplement to navigational orientation.
- Provide timely windshear alerts to assist in avoiding a windshear event.
- Provide timely indications of potential turbulent weather conditions to assist in navigation in the vicinity of turbulence.
- Provide timely indications of atmospheric threats.
- Provide timely indications of the presence of high-altitude ice crystals.

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1.4.1 Weather Detection

For weather detection, the airborne radar equipment should detect and display echoes from precipitation in a way that will allow flight crew analysis of weather. In this regard, the radar equipment should provide the following performance features:

- System Detection Range: The sensed and displayed radar range should provide sufficient indication to the flight crew consistent with the speed and maneuver performance of the aircraft in which it is installed, to allow for safe avoidance maneuvers.
- System Display Interpretation: Display features should allow for rapid pilot interpretation of weather characteristics over a wide dynamic range. These levels should be sufficient to allow interpretation of high precipitation gradients associated with turbulence.

1.4.2 Ground Mapping

In the case of ground mapping, the airborne radar equipment should be able to detect and display echoes from the surface of the earth to allow for in-flight analysis.

1.4.3 Forward-Looking Windshear Detection

For forward-looking windshear detection on fixed-wing aircraft, the airborne radar equipment detects areas containing windshear activity that is detectable by radar.

- It will be capable of correlating and generating appropriate alerts based on F-factor. This output should be clear, automatic, concise, and distinct to allow for rapid pilot interpretation.
- Selection of the forward-looking windshear detection mode should occur automatically during takeoff and landing phases of flight without pilot action.

1.4.4 Forward-Looking Turbulence Detection

For forward-looking turbulence detection on fixed-wing aircraft, the airborne radar equipment detects areas containing convective turbulence activity.

- The intended function is to provide the flight crew with a situational display of regions ahead of the aircraft that present potential hazards to the aircraft under weather conditions that permit radar detection of turbulence.
- The operational goal of such equipment is to display areas of significant turbulence in such a manner as to allow the flight crew the ability to make operational decisions on how to prepare for and if possible, avoid high-risk areas of turbulence. This will place a requirement on the timeliness and location accuracy of the indications on the display.

1.4.5 Atmospheric Threat Awareness

Airborne weather radar equipment may process atmospheric information such as reflectivity, velocity, spectral width, or other information available to the radar, either individually or in combination, to provide atmospheric threat information.

- The resulting cockpit display provides valid, timely, and current advisory information to the flight crew to enhance their situational awareness of atmospheric activity and assist with atmospheric threat avoidance decisions.
- This function should not adversely impact flight crew workload.

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1.4.6 High-Altitude Ice Crystal Detection

Airborne weather radar equipment may process atmospheric information such as reflectivity, velocity, spectral width, or other information available to the radar, either individually or in combination, to provide High-Altitude Ice Crystal information.

- The intended function is to provide the flight crew with a situational display of regions ahead of the aircraft that present potential hazards to the aircraft under weather conditions that permit radar detection of significant concentrations of ice crystals.
- The operational goal of such equipment is to display areas that contain a significant concentration of ice crystals in such a manner as to allow the flight crew the ability to make operational decisions on how to prepare for and if possible, avoid these areas. This will place a requirement on the timeliness and location accuracy of the indications on the display.

1.5 Assumptions

For radar functions that rely on specified accuracies of other aircraft systems, see Paragraph 2.1.8. Any other assumptions are stated in the corresponding requirements section for each function.

1.6 Test Procedures

The test procedures specified in this document demonstrate compliance with the performance requirements defined in Subsection 2.2. Users of this document should not infer performance requirements based on Test Procedures.

The order of tests specified suggests that the equipment be subjected to a succession of tests as it moves from design, and design qualification, into operational use. For example, it is expected that compliance with the requirements of Section 2 have been demonstrated as a precondition to satisfactory completion of the installed system tests of Section 3.

Environmental Tests

Subsection 2.3 defines the environmental test requirements. The procedures and their associated limits provide a laboratory means of determining the electrical and mechanical performance of the equipment under environmental conditions expected to be encountered in actual operations.

Unless otherwise specified, the environmental conditions and test procedures contained in the latest revision of RTCA\DO-160, *Environmental Conditions and Test Procedures for Airborne Equipment* will be used to demonstrate equipment compliance. You may use RTCA DO-160E or later revision. In this document, the requirements of European Organization for Civil Aviation Equipment (EUROCAE) ED-14E (or later revision) corresponding to the specified requirements of RTCA DO-160E (or later revision) also apply.

Bench Tests and Engineering Flight Evaluations

Subsection 2.4 specifies bench test and engineering flight evaluation procedures. The bench tests detailed in Paragraph 2.4.3 provide a laboratory means of demonstrating compliance with the requirements of Subsection 2.2. The engineering flight evaluations in Paragraph 2.4.4 serve to verify the intended function(s) of the radar system. Equipment manufacturers may use test results as design guidance, for monitoring manufacturing compliance and, in certain cases, for obtaining formal approval of equipment design. Installers may use data from the engineering flight evaluations to support installation approval activities.

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Installed Equipment Considerations

Tests for the installed equipment are included when performance cannot be adequately determined through bench testing or engineering flight evaluations.

Section 3 specifies the installed equipment test procedures and their associated limits. Although bench and environmental test procedures are not included with the installed equipment tests, their successful completion is a precondition to completion of the installed tests. In certain instances, however, installed equipment tests may be used in lieu of bench test simulation of such factors as power supply characteristics, interference from or to other equipment installed on the aircraft, etc. Installed tests are normally performed under two conditions:

- With the aircraft on the ground, using simulated or operational system inputs.
- With the aircraft in flight, using radar targets of opportunity.

Test results may be used to demonstrate functional performance in the intended operational environment. In addition, the procedures may be used as an operational check of equipment performance following corrective maintenance.

Operational Tests

Operational tests are specified in Section 4. This section provides considerations for operational characteristics that may be useful in conjunction with other systems on the final aircraft installation or unique to the final aircraft installation.

1.7 Definition of Terms

SHALL: A mandatory requirement. An approved design must comply with every applicable requirement. This can be assured by inspection, test, analysis, or demonstration.

SHOULD: A recommendation that would typically improve the system/equipment but does not constitute a requirement.

MAY: A permission that would likely improve the system/equipment but does not constitute a requirement.

1.8 Acronyms, Abbreviations, and Initialisms

AC	Advisory Circular
ADWRS	Airborne Doppler Weather Radar Simulation
AEH	Airborne Electronic Hardware
AGC	Automatic Gain Control
AGL	Altitude above ground level
AMS	Aviation, Range and Aerospace Meteorology
ARINC	Aeronautical Radio, Inc.
ASCII	American Standard Code for Information Interchange
ATP	Acceptance Test Procedure
CFR	Code of Federal Regulations
CPI	Coherent Processing Interval
CW	Continuous Wave
DAL	Design Assurance Level
DC	Direct Current
DFW	Dallas-Fort Worth Airport
DO	Document
DOT	Department of Transportation

ED	EUROCAE Document
ESA	Electronically Steered Antenna
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration
FBAR	Averaged F-Factor
FCC	Federal Communications Commission
FFT	Fast Fourier Transform
FLWS	Forward-Looking Windshear
FS	Feasibility Study
HAIC	High Altitude Ice Crystals
ICAS	International Council of the Aeronautical Sciences
IEEE	Institute of Electrical and Electronics Engineers
IF	Intermediate Frequency
INS	Inertial Navigation System
IR	Infrared
IWC	Ice Water Content
JAWS	Joint Airport Weather Studies
KTAS	Knots True Air Speed
LLWAS	Low Level Windshear Alert System
MCY	Miles City Airport
MDS	Minimum Discernible Signal
NMI	Nautical Mile
MOPS	Minimum Operational Performance Standards
MSL	Altitude above Mean Sea Level
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NF	Noise Figure
OET	FCC Office of Engineering and Technology
OU	University of Oklahoma
PDF	Probability Density Function
PI	Performance Index
PMC	Program Management Committee
RF	Radio Frequency
RMS	Root Mean Square
RX	Received signal
SAE	Society of Automotive Engineers
SC	Special Committee
SG	Subgroup
SNR	Signal to Noise Ratio
STC	Sensitivity Time Control
TAS	True Air Speed
TASS	Terminal Area Simulation System
TDWR	Terminal Doppler Weather Radar
TSO	Technical Standard Order
UTC	Coordinated Universal Time
UUT	Unit Under Test
VFR	Visual Flight Rules
VR	Rotation Velocity
WG	Working Group

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1.9 References

Items marked with an asterisk (*) may be found in the RTCA Store, associated with DO-220B, or requested by emailing info@rtca.org.

1.9.1 General

Unless otherwise indicated, the latest revisions of the listed documents apply.

[G-1] RTCA DO-155, *Minimum Performance Standards - Airborne Low-Range Radar Altimeters*

[G-2] RTCA DO-213, *Minimum Operational Performance Standards for Nose-Mounted Radomes*.

[G-3] AC 20-68, *Recommended Radiation Safety Precautions for Ground Operation of Airborne Weather Radar*

[G-4] AC 20-115, *Airborne Software Development Assurance Using EUROCAE ED-12( ) and RTCA DO-178( )*

[G-5] AC 20-152, *RTCA, Inc., Document RTCA/DO-254, Design Assurance Guidance for Airborne Electronic Hardware*

[G-6] AC 20-182, *Airworthiness Approval for Aircraft Weather Radar Systems*

[G-7] AC 25-11, *Electronic Flight Displays*

[G-8] AC 23.1309-1, *System Safety Analysis and Assessment for Part 23 Airplanes*

[G-9] AC 25.1309-1, *System Design and Analysis*

[G-10] AC 27-1, *Certification of Normal Category Rotorcraft*

[G-11] AC 29-2, *Certification of Transport Category Rotorcraft*

[G-12] AC 25.1302-1, *Installed Systems and Equipment for Use by the Flightcrew*

[G-13] AC 25.1322-1, *Flight Crew Alerting*

[G-14] ARINC 708A, *Airborne Weather Radar with Forward Looking Windshear Detection Capability*

[G-15] TSO-C63, *Airborne Weather Radar Equipment*

[G-16] DOT/FAA/CT-96/01, *Human Factors Design Guide Update (Report Number DOT/FAA/CT-96/01): A Revision to Chapter 8 - Human Interface Guidelines.* This document can be accessed on the Internet at http://www.hf.faa.gov.

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[W-8] Wonnacott, T. H. and R. J. Wonnacott, Introductory Statistics, John Wiley & Sons, New York, 1969

[W-9] *NASA Windshear Database Models, NASA Langley Research Center

[W-10] *ADWRS, Airborne Doppler Weather Radar Simulation program, NASA Langley Research Center.[1]

1.9.3 Forward-Looking Turbulence Detection

[T-1] *Bowles, Roland L. and Bill K. Buck, *A Methodology for Determining Statistical Performance Compliance for Airborne Doppler Radar with Forward-Looking Turbulence Detection Capability*, NASA/CR-2009-215769 "Corrected Copy", 2009

[T-2] *NASA Turbulence Event Scenarios, NASA Langley Research Center

[1] NASA developed the initial version of ADWRS in FORTRAN. They continue to refine and develop this simulation, including versions in other computer languages. Submit any requests for this software in computer languages other than FORTRAN directly to NASA. NASA will provide source code in the requested computer language if it has already been developed and is available for release. Contact NASA directly at Software Release Authority, NASA Langley Research Center, Hampton, VA 23681-2199

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1.9.4 High-Altitude Ice Crystal Detection

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[I-5] *NASA Ice Crystal Database Models, NASA Langley Research Center

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