

RTCA, Inc.
1828 L Street, NW, Suite 805
Washington, DC 20036-5133 USA

**Minimum Operational Performance Standards
for Global Positioning System / Wide Area
Augmentation System Airborne Equipment**

RTCA DO-229C
Supersedes DO-229B
November 28, 2001

Prepared by: SC-159
© 2001 RTCA, Inc.

Copies of this document may be obtained from

RTCA, Inc.

Telephone: 202-833-0339

Facsimile: 202-833-9434

Internet: www.rtca.org

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

FOREWORD

This report was prepared by Special Committee 159 (SC-159) and approved by the RTCA Program Management Committee (PMC) on November 28, 2001.

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 Federal Advisory Committee 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.

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 announced by the U.S. government organization or agency having statutory jurisdiction over any matters to which the recommendations relate.

This page intentionally left blank.

Currently in preview, click buy full version

TABLE OF CONTENTS

1	PURPOSE AND SCOPE	1
1.1	Introduction	1
1.2	System Overview	3
1.2.1	Wide Area Augmentation System	3
1.2.2	GNSS Satellite Signal Characteristics	3
1.2.2.1	GPS Signal Characteristics	3
1.2.2.2	WAAS Signal Characteristics	4
1.3	Operational Goals	5
1.3.1	Intended Operational Applications	5
1.3.2	Operational Environment	5
1.3.3	International Compatibility	6
1.4	Equipment Classes	7
1.4.1	Functional Classes	7
1.4.2	Operational Classes	7
1.4.3	Relation of Classes to Document Organization	9
1.5	Aiding and Multiple Sensors	9
1.6	Test Considerations	10
1.6.1	Environmental Tests	10
1.6.2	Bench Tests	10
1.6.3	Installed Tests	11
1.7	Definition of Key Terms	11
1.7.1	General Terms	11
1.7.2	Alert Limits and Protection Levels	12
1.7.3	Fault Detection and Exclusion (FDE) Terms	13
1.8	Assumptions and Approach to Selected Issues	18
1.8.1	General	18
1.8.1.1	GPS Constellation and WAAS Ground/Space Segments	18
1.8.1.2	GPS/WAAS Performance	18
1.8.1.3	Applicability	19
1.8.1.4	Interoperability	19
1.8.1.5	Integrity Monitoring	19
1.8.1.6	Navigational Waypoints	19
1.8.1.7	RF Interference	20
1.8.1.8	Time of Applicability of Information in the WAAS Signal-in-Space	20
1.8.1.9	Change of Broadcast Ephemeris	20
1.8.1.10	WAAS Regional Message Type (Message Type 27 and 28)	20
1.8.2	Precision Approach Applications	20
1.8.2.1	WAAS Performance for Precision Approach Operations	20
1.8.2.2	Precision Approach Path-in-Space	21
1.8.2.3	LNAV/VNAV and Precision Approach Position Integrity	21
1.8.2.4	Vector-to-Final (VTF) Precision Approach	21
2	EQUIPMENT PERFORMANCE AND TEST PROCEDURES	23
2.1	General Requirements	23
2.1.1	Requirements Applicable to Beta, Gamma, and Delta Equipment	23

2.1.1.1	General Requirements for All Navigation Modes	23
2.1.1.1.1	Airworthiness	23
2.1.1.1.2	General Performance	23
2.1.1.1.3	Fire Resistance	23
2.1.1.1.4	Equipment Interfaces	23
2.1.1.1.5	Effects of Test	23
2.1.1.2	GPS Signal Processing Requirements	23
2.1.1.3	WAAS Signal Processing Requirements	24
2.1.1.3.1	Acquisition and Track	24
2.1.1.3.2	Demodulation and Forward Error Correction (FEC) Decoding	25
2.1.1.3.3	WAAS Satellite Pseudorange Determination	25
2.1.1.4	WAAS Message Processing	25
2.1.1.4.1	Message Type 0 — Don't Use for Safety Applications	25
2.1.1.4.2	Message Type 1 — PRN Mask Assignments	26
2.1.1.4.3	Message Types 2-5 and 24 — Fast Clock Corrections	26
2.1.1.4.4	Message Type 6 — Integrity Information	26
2.1.1.4.5	Message Type 7 — Fast Correction Degradation	26
2.1.1.4.6	Message Type 9 — WAAS Satellite Navigation Message	26
2.1.1.4.7	Message Type 17 — WAAS Satellite Almanac	26
2.1.1.4.8	Message Type 27 — WAAS Service Message	26
2.1.1.4.9	Message Timeout Periods	27
2.1.1.4.10	Combining Data from Separate Broadcasts	29
2.1.1.4.11	Message Type 24 and 25 Long-Term Corrections and Message Type 9 GEO Navigation Data	29
2.1.1.4.12	Application of Differential Correction	30
2.1.1.4.13	Message Type 28 — Clock-Ephemeris Covariance Matrix Message	31
2.1.1.5	Satellite Integrity Status	31
2.1.1.5.1	Step Detector	31
2.1.1.5.2	WAAS UNHEALTHY Designation	31
2.1.1.5.3	WAAS UNMONITORED Designation	32
2.1.1.5.4	WAAS HEALTHY Designation	32
2.1.1.5.5	GPS UNHEALTHY Designation	32
2.1.1.5.6	GPS HEALTHY	33
2.1.1.6	Satellite Selection	33
2.1.1.7	Initial Acquisition Time	34
2.1.1.8	Satellite Acquisition Time	35
2.1.1.8.1	GPS Satellite Acquisition Time	35
2.1.1.8.2	WAAS Satellite Acquisition Time	35
2.1.1.9	Satellite Reacquisition Time	35
2.1.1.10	Sensitivity and Dynamic Range	35
2.1.1.11	Equipment Burnout Protection	37
2.1.1.12	Integrity in the Presence of Interference	37
2.1.1.13	Alerts/Outputs	38
2.1.1.13.1	Protection Level	38
2.1.1.13.2	Navigation Alert	38
2.1.2	Requirements for En Route and Terminal Mode	39
2.1.2.1	Accuracy	39
2.1.2.2	Integrity Requirements	39
2.1.2.2.1	Development Assurance	39
2.1.2.2.1.1	Hardware Compliance	39
2.1.2.2.1.2	Software Compliance	40
2.1.2.2.2	Integrity Monitoring	40

2.1.2.2.2.1	WAAS-Provided Integrity Monitoring	40
2.1.2.2.2.2	FDE-Provided Integrity Monitoring	40
2.1.2.2.2.2.1	Time-to-Alert	41
2.1.2.2.2.2.2	Missed Alert Probability	41
2.1.2.2.2.2.3	False Alert Probability	41
2.1.2.2.2.2.4	Failed Exclusion Probability	42
2.1.2.2.2.2.5	Availability	42
2.1.2.3	Equipment Reliability	42
2.1.2.4	Satellite Tracking Capability	42
2.1.2.5	Dynamic Tracking	42
2.1.2.6	Position Output	42
2.1.2.6.1	Position Output Update Rate	43
2.1.2.6.2	Position Output Latency	43
2.1.3	Requirements for Nonprecision Approach Mode	43
2.1.3.1	Accuracy	43
2.1.3.2	Integrity Requirements	44
2.1.3.2.1	Development Assurance	44
2.1.3.2.2	Integrity Monitoring	44
2.1.3.2.2.1	WAAS-Provided Integrity Monitoring	44
2.1.3.2.2.2	FDE-Provided Integrity Monitoring	44
2.1.3.2.2.2.1	Time-to-Alert	44
2.1.3.2.2.2.2	Missed Alert Probability	44
2.1.3.2.2.2.3	False Alert Probability	44
2.1.3.2.2.2.4	Failed Exclusion Probability	44
2.1.3.2.2.2.5	Availability	44
2.1.3.3	Equipment Reliability	45
2.1.3.4	Satellite Tracking Capability	45
2.1.3.5	Dynamic Tracking	45
2.1.3.6	Position Output	45
2.1.3.6.1	Position Output Update Rate	45
2.1.3.6.2	Position Output Latency	45
2.1.3.7	WAAS Message Processing	45
2.1.3.8	Application of Differential Correction Terms	45
2.1.3.9	Satellite Selection	45
2.1.4	Requirements for LNAV/VNAV Operations	45
2.1.4.1	Accuracy	46
2.1.4.1.1	Smoothing	46
2.1.4.1.2	Measurement Quality Monitoring	46
2.1.4.1.3	Accuracy	47
2.1.4.1.3.1	GPS Satellites	47
2.1.4.1.3.2	WAAS Satellites	48
2.1.4.1.3.3	Position Solution	48
2.1.4.2	Integrity Requirements	48
2.1.4.2.1	Development Assurance	48
2.1.4.2.2	Integrity Monitoring	48
2.1.4.2.2.1	WAAS-Provided Integrity Monitoring	48
2.1.4.2.2.2	Fault Detection-Provided Integrity Monitoring	49
2.1.4.2.2.2.1	Frequency of Fault Detection	49
2.1.4.2.2.2.2	Missed Alert	49
2.1.4.2.2.2.3	False Alert	49
2.1.4.2.2.2.4	Availability	49
2.1.4.3	Equipment Reliability	49

2.1.4.4	Satellite Tracking Capability	49
2.1.4.5	Tracking Constraints	49
2.1.4.5.1	GPS Tracking Constraints	50
2.1.4.5.2	SBAS Tracking Constraints	52
2.1.4.6	Correlation Peak Validation	52
2.1.4.7	Dynamic Tracking	53
2.1.4.8	Position Output	53
2.1.4.8.1	Position Output Update Rate	53
2.1.4.8.2	Position Output Latency	53
2.1.4.9	WAAS Message Processing	53
2.1.4.9.1	Message Type 2-5, 6 and 24 Fast Clock Corrections	53
2.1.4.9.2	Message Types 24 and 25 Long-Term Corrections and Message Type 9 GEO Navigation Data	53
2.1.4.9.3	Message Type 18 — Ionospheric Grid Point Masks	54
2.1.4.9.4	Message Type 26 — Ionospheric Grid Point Delays	54
2.1.4.9.5	Message Types 7 and 10 — Degradation Parameters	54
2.1.4.10	Application of Differential Correction Terms	54
2.1.4.10.1	Application of Clock and Ephemeris Corrections	54
2.1.4.10.2	Application of Ionospheric Corrections	54
2.1.4.10.3	Application of Tropospheric Corrections	54
2.1.4.11	Satellite Selection	55
2.1.4.12	Alerts/Outputs/Inputs	55
2.1.4.12.1	Protection Level	55
2.1.4.12.2	Navigation Alert	56
2.1.5	Requirements for APV-II and GLS Precision Approach Operations	56
2.1.5.1	Accuracy	56
2.1.5.2	Integrity Requirements	56
2.1.5.2.1	Development Assurance	56
2.1.5.2.1.1	Hardware Compliance	56
2.1.5.2.1.2	Software Compliance	57
2.1.5.2.2	Integrity Monitoring	57
2.1.5.2.2.1	WAAS-Provided Integrity Monitoring	57
2.1.5.2.2.2	Fault Detection-Provided Integrity Monitoring	57
2.1.5.2.2.2.1	Frequency of Fault Detection	57
2.1.5.2.2.2.2	Missed Alert	57
2.1.5.2.2.2.3	False Alert	58
2.1.5.2.2.2.4	Availability	58
2.1.5.3	Equipment Reliability	58
2.1.5.3.1	GPS Satellites	58
2.1.5.3.2	GEO Satellites	58
2.1.5.4	Satellite Tracking Capability	58
2.1.5.5	Tracking Constraints	58
2.1.5.5.1	GPS Tracking Constraints	58
2.1.5.5.2	SBAS Tracking Constraints	58
2.1.5.6	Correlation Peak Validation	58
2.1.5.7	Dynamic Tracking	58
2.1.5.8	Position Output	58
2.1.5.8.1	Position Output Update Rate	58
2.1.5.8.2	Position Output Latency	59
2.1.5.9	WAAS Message Processing	59
2.1.5.9.1	Message Type 2-5, 6 and 24 Fast Clock Corrections	59

2.1.5.9.2	Message Types 24 and 25 Long-Term Corrections and Message Type 9 GEO Navigation Data.....	59
2.1.5.9.3	Message Type 18 — Ionospheric Grid Point Masks	59
2.1.5.9.4	Message Type 26 — Ionospheric Grid Point Delays	59
2.1.5.9.5	Message Types 7 and 10 — Degradation Parameters	59
2.1.5.10	Application of Differential Correction Terms.....	59
2.1.5.10.1	Application of Clock and Ephemeris Corrections	60
2.1.5.10.2	Application of Ionospheric Corrections	60
2.1.5.10.3	Application of Tropospheric Corrections	60
2.1.5.11	Satellite Selection	60
2.1.5.12	Alerts/Outputs/Inputs	60
2.1.5.12.1	Protection Level	61
2.1.5.12.2	Navigation Alert	61
2.2	Class Gamma Requirements.....	61
2.2.1	Class Gamma General Requirements	61
2.2.1.1	General Human Factors Requirements and Applicable Documents.....	61
2.2.1.1.1	Controls.....	62
2.2.1.1.1.1	Operation	62
2.2.1.1.1.2	Control Labels	62
2.2.1.1.2	Equipment Operating Procedures.....	63
2.2.1.1.3	Minimum Workload Functions.....	63
2.2.1.1.4	Displays	65
2.2.1.1.4.1	Discriminability	65
2.2.1.1.4.2	Brightness, Contrast and Color	65
2.2.1.1.4.3	Angle of Regard.....	66
2.2.1.1.4.4	Symbology.....	66
2.2.1.1.4.5	Alphanumerics.....	66
2.2.1.1.4.6	Moving Map.....	66
2.2.1.1.4.7	Primary Navigation Display	67
2.2.1.1.4.8	Bearing Labels.....	67
2.2.1.1.5	Annunciations.....	67
2.2.1.1.5.1	Annunciators	67
2.2.1.1.5.2	Messages	67
2.2.1.1.6	Set of Standard Function Labels.....	68
2.2.1.1.7	Set of Standard Abbreviations and Acronyms	68
2.2.1.2	Path Selection	72
2.2.1.2.1	Flight Plan Selection.....	72
2.2.1.2.2	Flight Plan Review	72
2.2.1.2.3	Flight Plan Activation.....	73
2.2.1.2.4	Waypoint Sequencing.....	73
2.2.1.2.5	Manually-Selected Active Waypoint	73
2.2.1.2.5.1	Direct To	73
2.2.1.2.5.2	TO/FROM Course Selection	74
2.2.1.2.5.3	Manually-Selected Waypoint and Waypoint Sequencing	74
2.2.1.2.6	User-Defined Waypoints	74
2.2.1.2.7	Emergency Procedures	74
2.2.1.3	Path Definition	74
2.2.1.3.1	Initial Fix (IF)	75
2.2.1.3.2	Fixed Waypoint to a Fixed Waypoint (TF)	75
2.2.1.3.3	DME Arcs (AF) and Constant Radius to a Fix (RF)	75
2.2.1.3.4	Direct-To (DF)	76
2.2.1.3.5	Course to a Fix Waypoint (CF).....	77

2.2.1.3.6	FROM Leg	77
2.2.1.3.7	Fly-By Turns	77
2.2.1.3.7.1	Fly-By Turn Indications	77
2.2.1.3.7.2	Fly-By Theoretical Transition Area	79
2.2.1.3.7.3	Acceptable Means of Defining Fly-By Turns	80
2.2.1.3.8	Fly Over Turns	80
2.2.1.3.9	Fixed Radius Turns	81
2.2.1.3.10	Waypoint Sequencing	81
2.2.1.3.11	Holding Patterns/Procedure Turns	82
2.2.1.3.12	Magnetic Course	83
2.2.1.3.13	Dead Reckoning	83
2.2.1.3.14	Fuel Management and Alerting	83
2.2.1.3.15	Geodesic Path Computation Accuracy	84
2.2.1.3.16	Parallel Offsets	84
2.2.1.4	Navigation Displays	85
2.2.1.4.1	Primary Navigation Display	85
2.2.1.4.2	Non-Numeric Display/Output Characteristics	85
2.2.1.4.2.1	Electrical Output	85
2.2.1.4.2.2	Display	85
2.2.1.4.3	Active Waypoint Distance Display	86
2.2.1.4.4	Active Waypoint Bearing Display	86
2.2.1.4.5	Track Displays	86
2.2.1.4.5.1	Desired Track	86
2.2.1.4.5.2	Track Angle	86
2.2.1.4.5.3	Track Angle Error	86
2.2.1.4.6	Display of TO or FROM Operations	86
2.2.1.4.7	Waypoint Bearing/Distance Display	86
2.2.1.4.8	Estimate of Position Uncertainty	87
2.2.1.4.9	Magnetic Course	87
2.2.1.4.10	Ground Speed	87
2.2.1.4.11	Aircraft Present Position	87
2.2.1.5	Database Requirements	87
2.2.1.5.1	Access	87
2.2.1.5.2	Content	87
2.2.1.5.3	Database Standard	88
2.2.1.5.4	Reference Coordinate System	88
2.2.1.5.4.1	Incorporation of Conversion Algorithms	89
2.2.1.5.4.2	Operational Approval	89
2.2.1.6	Alerts	89
2.2.1.6.1	Caution Associated with Loss of Integrity Monitoring	89
2.2.1.6.2	Caution Associated with Loss of Navigation	90
2.2.1.7	Mode Switching Requirements	90
2.2	Class Gamma Requirements for En Route / Terminal Operation	93
2.2.2.1	General Human Factors Requirements	93
2.2.2.2	Path Selection	93
2.2.2.3	Path Definition	93
2.2.2.4	Navigation Displays	93
2.2.2.4.1	Primary Navigation Displays	93
2.2.2.4.2	Non-Numeric Cross-Track Deviation	93
2.2.2.4.3	Numeric Cross-Track Deviation	94
2.2.2.4.4	Displayed Data Update Rate	94
2.2.2.4.5	Display Update Latency	94

2.2.2.5	Database Requirements	94
2.2.2.6	Alerts	94
2.2.2.6.1	Alert Limits	94
2.2.2.6.2	Caution Associated with Loss of Integrity Monitoring	94
2.2.2.6.3	Caution Associated with Loss of Navigation	94
2.2.2.7	En Route/Terminal Mode Switching Requirements	95
2.2.2.7.1	En Route Mode Switching Requirements	95
2.2.2.7.1.1	Entry Criteria	95
2.2.2.7.1.2	Exit Criteria	95
2.2.2.7.1.3	Display Transition Requirements	95
2.2.2.7.2	Terminal Mode Switching Requirements	95
2.2.2.7.2.1	Entry Criteria	95
2.2.2.7.2.2	Exit Criteria	95
2.2.2.7.2.3	Display Transition Requirements	96
2.2.3	Class Gamma Requirements for Nonprecision Approach Operation	96
2.2.3.1	General Human Factors Requirements	96
2.2.3.2	Path Selection	96
2.2.3.2.1	Approach Selection	96
2.2.3.2.2	Missed Approach Sequencing	96
2.2.3.3	Path Definition	97
2.2.3.3.1	Approach Path Definition	97
2.2.3.3.2	Missed Approach Path Definition	98
2.2.3.3.3	Departure Path Definition	99
2.2.3.3.4	Vertical Path for NPA Procedures	99
2.2.3.4	Navigation Displays	100
2.2.3.4.1	Primary Navigation Displays	100
2.2.3.4.2	Non-Numeric Cross-Track Deviation	100
2.2.3.4.3	Numeric Cross-Track Deviation	100
2.2.3.4.4	Missed Approach Waypoint Distance Display	100
2.2.3.4.5	Missed Approach Waypoint Bearing Display	101
2.2.3.4.6	Displayed Data Update Rate	101
2.2.3.4.7	Display Update Latency	101
2.2.3.5	Database Requirements	101
2.2.3.6	Alerts	102
2.2.3.6.1	Alert Limits	102
2.2.3.6.2	Caution Associated with Loss of Integrity Monitoring	102
2.2.3.6.3	Caution Associated with Loss of Navigation	102
2.2.3.7	Mode Switching Requirements	102
2.2.3.7.1	Nonprecision Approach Mode Switching Requirements	102
2.2.3.7.1.1	Entry Criteria	102
2.2.3.7.1.2	Exit Criteria	102
2.2.3.7.1.3	Display Transition Requirements	103
2.2.3.7.2	Departure Requirements	103
2.2.3.7.2.1	Entry Criteria	103
2.2.3.7.2.2	Exit Criteria	103
2.2.3.7.2.3	Display Transition Requirements	103
2.2.4	Class Gamma Requirements for LNAV/VNAV Operations	103
2.2.4.1	General Human Factors Requirements	103
2.2.4.2	Path Selection	104
2.2.4.2.1	5-Digit Channel Selection	104
2.2.4.2.2	Approach Name Selection	104
2.2.4.2.3	Missed Approach Sequencing	104

2.2.4.3	Path Definition	104
2.2.4.3.1	Approach Path Definition	104
2.2.4.3.2	Missed Approach Path Definition	105
2.2.4.3.3	Navigation Center Offset	105
2.2.4.4	Navigation Displays	105
2.2.4.4.1	Primary Navigation Displays	105
2.2.4.4.2	Non-Numeric Lateral Cross-Track Deviation	106
2.2.4.4.3	Numeric Lateral Cross-Track Deviation	108
2.2.4.4.4	Non-Numeric Vertical Deviation	108
2.2.4.4.5	Missed Approach Waypoint/LTP/FTP Distance Display	110
2.2.4.4.6	Missed Approach Waypoint/LTP/FTP Bearing Display	110
2.2.4.4.7	Displayed Data Update Rate	110
2.2.4.4.8	Display Update Latency	110
2.2.4.4.9	Display of Vertical Accuracy	110
2.2.4.5	Database Requirements	110
2.2.4.5.1	Content	110
2.2.4.5.2	Data Integrity	111
2.2.4.6	Alerts	111
2.2.4.6.1	Alert Limits	111
2.2.4.6.2	Caution Associated with Loss of Integrity Monitoring	112
2.2.4.6.3	Caution Associated with Loss of Navigation	112
2.2.4.6.4	Low Altitude Alert	113
2.2.4.6.5	Alerting Scheme	113
2.2.4.7	LNAV/VNAV Approach Mode Switching Requirements	114
2.2.4.7.1	Entry Criteria	114
2.2.4.7.2	Exit Criteria	114
2.2.4.7.3	Display Transition	115
2.2.4.7.4	Advisory of LNAV/VNAV Availability	115
2.2.5	Class Gamma Requirements for APV-II and GLS Precision Approach Operations	116
2.2.5.1	General Human Factors Requirements	116
2.2.5.2	Path Selection	116
2.2.5.2.1	5-Digit Channel Selection	116
2.2.5.2.2	Approach Name Selection	116
2.2.5.2.3	Missed Approach Sequencing	116
2.2.5.2.4	Selection of the Type of Approach with Vertical Guidance	116
2.2.5.3	Path Definition	116
2.2.5.3.1	Approach Path Definition	116
2.2.5.3.2	Missed Approach Path Definition	116
2.2.5.3.3	Navigation Center Offset	116
2.2.5.4	Navigation Displays	116
2.2.5.4.1	Primary Navigation Displays	116
2.2.5.4.2	Non-Numeric Lateral Cross-Track Deviation	116
2.2.5.4.3	Numeric Lateral Cross-Track Deviation	118
2.2.5.4.4	Non-Numeric Vertical Deviation	118
2.2.5.4.5	Missed Approach Waypoint/LTP/FTP Distance Display	119
2.2.5.4.6	Missed Approach Waypoint/LTP/FTP Bearing Display	119
2.2.5.4.7	Displayed Data Update Rate	119
2.2.5.4.8	Display Update Latency	119
2.2.5.4.9	Display of Vertical Accuracy	119
2.2.5.5	Database Requirements	119
2.2.5.5.1	Content	119
2.2.5.5.2	Data Integrity	120

2.2.5.6	Alerts	120
2.2.5.6.1	Alert Limits	120
2.2.5.6.2	Caution Associated with Loss of Integrity Monitoring	120
2.2.5.6.3	Caution Associated with Loss of Navigation	121
2.2.5.6.4	Low Altitude Alert	121
2.2.5.6.5	Alerting Scheme	121
2.2.5.7	Precision Approach Mode Switching Requirements	122
2.2.5.7.1	Entry Criteria	122
2.2.5.7.2	Exit Criteria	122
2.2.5.7.3	Display Transition	123
2.2.5.7.4	Advisory of GLS or APV-II Availability	123
2.3	Class Delta-4 Requirements for Precision Approach Operations	123
2.3.1	General Human Factors Requirements	123
2.3.2	Path Selection	123
2.3.3	Path Definition	124
2.3.4	Navigation Displays	124
2.3.4.1	Non-Numeric Cross-Track Deviation	124
2.3.4.2	Non-Numeric Vertical Deviation	124
2.3.4.3	Landing Threshold Point/Fictitious Threshold Point Distance Display	124
2.3.4.4	Displayed Data Update Rate	124
2.3.4.5	Displayed Data Update Latency	124
2.3.5	Database Requirements	124
2.3.6	Alerts	125
2.4	Airborne Equipment Performance — Environmental Conditions	125
2.4.1	Environmental Tests	125
2.4.1.1	Required Performance	126
2.4.1.1.1	Accuracy	126
2.4.1.1.2	Loss of Navigation Indication	126
2.4.1.1.3	Loss of Integrity Indication	126
2.4.1.1.4	Reserved	126
2.4.1.1.5	Sensitivity and Dynamic Range	126
2.4.1.1.6	Navigation Display	126
2.4.1.1.7	Database	126
2.4.1.1.8	Mode Annunciation	127
2.4.1.1.9	TO-TO and TO-FROM Capability	127
2.4.1.1.10	System Operating	127
2.4.1.2	Clarification of Environmental Tests	127
2.4.1.2.1	Power Input Tests	127
2.4.1.2.2	Icing Tests	127
2.4.1.2.3	RF Susceptibility Tests	127
2.4.1.2.4	Lightning Induced Transient Susceptibility Tests	127
2.4.1.2.5	Lightning Direct Effects Tests	128
2.4.1.2.6	Crash Safety Shock	128
2.5	Test Methods and Procedures	136
2.5.1	Test Cross Reference Matrix	139
2.5.2	WAAS Message Loss Rate Test	216
2.5.2.1	Evaluation of Message Loss Rate During the Measurement Accuracy Test	216
2.5.2.2	Test Procedure	216
2.5.2.3	Pass/Fail Determination	217
2.5.2.4	Evaluation of Message Loss Rate During the 24-Hour System Accuracy Test	217
2.5.2.4.1	Test Procedure	217

2.5.2.4.2	Pass/Fail Criteria	217
2.5.3	Step Detector Test	217
2.5.3.1	Verification of Step Detector Operation Without Exclusion Capability	217
2.5.3.2	Verification of No Interference with Fault Detection Algorithm	218
2.5.3.3	Verification of Step Detector Operation with Exclusion Capability	218
2.5.3.4	Verification of No Interference with Exclusion of the FDE Algorithm	218
2.5.4	Initial Acquisition Test Procedures	219
2.5.4.1	Simulator and Interference Conditions	219
2.5.4.2	Test Procedures	219
2.5.4.3	Pass/Fail Determination	220
2.5.5	Reserved	221
2.5.6	Satellite Reacquisition Time Test	221
2.5.6.1	Simulator and Interference Conditions	221
2.5.6.2	Test Procedures	222
2.5.6.3	Pass/Fail Determination	222
2.5.7	Interference Rejection Test	223
2.5.7.1	Simulator and Interference Conditions	223
2.5.7.2	Test Procedures	223
2.5.7.3	Pass/Fail Determination	224
2.5.8	Accuracy Tests	224
2.5.8.1	Measurement Accuracy Test	224
2.5.8.2	Simulator and Interference Conditions	224
2.5.8.2.1	Test Procedures	226
2.5.8.3	24-Hour Actual Satellite Accuracy Test	228
2.5.8.3.1	Test Procedure	228
2.5.8.3.2	Pass/Fail Criteria	229
2.5.9	Integrity Monitoring Test Procedures	229
2.5.9.1	General Test Conditions	229
2.5.9.1.1	Test Philosophy	229
2.5.9.1.2	GPS Constellation	229
2.5.9.1.3	Applicability of RTCA/DO-178B	229
2.5.9.1.4	Test Repetition	230
2.5.9.1.5	Protection Level/Alert Limit	230
2.5.9.1.6	Time-to-Alert	230
2.5.9.2	Availability Tests	230
2.5.9.3	Off-Line FDE Tests	231
2.5.9.3.1	Off-Line Test Setup	231
2.5.9.3.2	Selection of Geometries	232
2.5.9.3.3	Test Procedure	232
2.5.9.3.3.1	Class Gamma Equipment	233
2.5.9.3.3.2	Class Beta Equipment	233
2.5.9.3.4	Pass/Fail Criteria	234
2.5.9.4	False Alert Rate Test	234
2.5.9.4.1	False Alert Rate Simulations for Snapshot Algorithms	234
2.5.9.4.2	False Alert Rate Simulations for Non-Snapshot Algorithms	235
2.5.9.5	On-Line Verification Test	235
2.5.9.5.1	On-Target Computational Test	236
2.5.9.5.2	On-Line Behavioral Test	236
2.5.10	Precision Approach Fault Detection	236
2.5.10.1	General Test Conditions	237
2.5.10.1.1	Test Philosophy	237
2.5.10.1.2	GPS Constellation	237

2.5.10.1.3	Applicability of RTCA/DO-178B	237
2.5.10.1.4	Test Repetition	237
2.5.10.1.5	Protection Level/Alert Limit	237
2.5.10.1.6	Time-to-Alert	237
2.5.10.2	Availability Tests	237
2.5.10.3	Off-Line Missed Alert Tests	238
2.5.10.3.1	Off-Line Test Setup	238
2.5.10.3.2	Selection of Geometries	238
2.5.10.3.3	Test Procedures and Pass/Fail Criteria	238
2.5.10.3.4	False Alert Rate Test	239
2.5.10.4	On-Line Verification Test	239
2.5.10.4.1	On-Target Computational Test	240
2.5.10.4.2	On-Line Behavioral Test	240
2.5.11	Test Procedures for Class Gamma Equipment	240
2.5.11.1	General Gamma Bench Test Procedures	240
2.5.11.1.1	Simulated Flight Bench Test Procedures	241
2.5.11.1.1.1	Simulated Flight Plan Test 1	241
2.5.11.1.1.2	Simulated Flight Plan Test 2	242
2.5.11.1.2	Waypoint Distance Display	257
2.5.11.1.3	Equipment Response Time Test	258
2.5.11.1.4	Loss of Power and Navigation Cautions and Annunciations	258
2.5.11.1.5	Cross-Track Deviation Display Bench Test for En Route and Terminal	259
2.5.11.1.6	Cross-Track Deviation Display Test for NPA	265
2.5.11.2	Reserved	269
2.5.11.3	Human Factors Bench Tests	269
2.5.11.3.1	Equipment Usability	269
2.5.11.3.2	Display Brightness and Readability Test	269
2.5.11.3.3	Audible Alerts Test	272
2.5.11.3.4	Equipment Controls Test	272
3	INSTALLED EQUIPMENT PERFORMANCE	275
3.1	General Requirements	275
3.1.1	Installation Requirements	275
3.1.1.1	Accessibility	275
3.1.1.2	Interference Effects	275
3.1.1.3	Inadvertent Turnoff	276
3.1.2	Installed Equipment Performance Requirements	276
3.1.2.1	General Performance Requirements	276
3.1.2.2	Coverage	276
3.1.3	Conditions of Test	276
3.1.3.1	Test Environment	276
3.1.3.2	Associated Equipment or Systems	276
3.1.3.3	Environmental Conditions	276
3.1.3.4	Adjustment of Equipment	276
3.1.3.5	Warm-Up Period	276
3.1.4	Test Procedures for Installed Equipment Performance	276
3.1.4.1	Ground Test Procedures	277
3.1.4.1.1	Conformity Inspection	277
3.1.4.1.2	Lab/Bench Tests and Equipment Data Evaluation	277
3.1.4.1.3	Antenna Installation	277
3.1.4.1.4	Electromagnetic Compatibility	277
3.1.4.2	Flight Test Procedures	278

3.1.4.2.1	Electromagnetic Compatibility	278
3.2	Class Beta Equipment	278
3.3	Class Gamma Equipment	278
3.3.1	General Requirements for All Navigation Modes	278
3.3.1.1	Installation Requirements	278
3.3.1.1.1	Display Visibility	278
3.3.1.1.2	Control/Display Capability	278
3.3.1.1.3	Operation of Controls	279
3.3.1.1.4	Accessibility of Controls	279
3.3.1.1.5	Arrangement of Controls	279
3.3.1.2	Installed Equipment Performance Requirements	279
3.3.1.2.1	Cross-Track Deviation Display	279
3.3.1.2.2	Data Entry Capability	279
3.3.1.3	Test Procedures for Installed Equipment Performance	280
3.3.1.3.1	Ground Test Procedures	280
3.3.1.3.1.1	Cockpit Layout of Installed Equipment	280
3.3.1.3.1.2	Accuracy Test	280
3.3.1.3.1.3	Power Supply Fluctuations	280
3.3.1.3.2	Flight Test Procedures	280
3.3.1.3.2.1	Switching and Transfer Functions	280
3.3.1.3.2.2	Failure Modes/Annunciations	280
3.3.1.3.2.3	Steering Response	280
3.3.1.3.2.4	Displayed GPS/WAAS Navigation Parameters	280
3.3.1.3.2.5	Controls Accessibility, Usability and Visibility	281
3.3.1.3.2.6	Crew Workload	281
3.3.1.3.2.7	Continuity of Navigation Data	281
3.3.1.3.2.8	Fly-By Turn Performance	281
3.3.2	Class Gamma Equipment to Support En Route, Terminal Area and Nonprecision Approach Navigation	281
3.3.2.1	Installation Requirements	281
3.3.2.2	Installed Equipment Performance Requirements	281
3.3.2.2.1	General Performance Requirements	281
3.3.2.2.2	Waypoint Input and Display	281
3.3.2.3	Test Procedures for Installed Equipment Performance	281
3.3.2.3.1	Ground Test Procedures	281
3.3.2.3.2	Flight Test Procedures	281
3.3.2.3.2.1	Equipment Operation	281
3.3.2.3.2.2	Accuracy Test	282
3.3.2.3.2.3	Flight Technical Error	282
3.3.2.3.2.4	Lateral Maneuver Anticipation	282
3.3.2.3.2.5	Automatic Lateral Change	282
3.3.2.3.2.6	Direct-To Function	282
3.3.3	Class Gamma Equipment to Support LNAV/VNAV Navigation	282
3.3.3.1	Installation Requirements	282
3.3.3.1.1	Display Visibility	282
3.3.3.2	Installed Equipment Performance Requirements	283
3.3.3.2.1	General Performance Requirements	283
3.3.3.3	Test Procedures for Installed Equipment Performance	283
3.3.3.3.1	Ground Test Procedures	283
3.3.3.3.2	Flight Test Procedures	283
3.3.3.3.2.1	Equipment Operation	283

3.3.3.3.2.2	Flight Technical Error	283
3.3.3.3.2.3	Steering Response	283
3.3.3.3.2.4	Automatic Lateral Change	283
3.3.3.3.2.5	Missed Approach	283
3.3.3.3.2.6	Horizontal Deviation Display	283
3.3.4	Class Gamma Equipment to Support LNAV/VNAV Navigation.	284
3.3.4.1	Installation Requirements	284
3.3.4.1.1	Display Visibility	284
3.3.4.2	Installed Equipment Performance Requirements	284
3.3.4.2.1	General Performance Requirements	284
3.3.4.2.2	Vertical Path Deviation Display	284
3.3.4.3	Test Procedures for Installed Equipment Performance.	284
3.3.4.3.1	Ground Test Procedures	284
3.3.4.3.1.1	Antenna to Aircraft Navigation Reference Offset	284
3.3.4.3.2	Flight Test Procedures	284
3.3.4.3.2.1	Differential GPS/WAAS Operation.	284
3.3.4.3.2.2	Flight Technical Error	285
3.3.4.3.2.3	Continuity of Navigation Data.	285
3.3.5	Class Gamma Equipment to Support Precision Approach (APV-II, GLS) Navigation	285
3.3.5.1	Installation Requirements	285
3.3.5.1.1	Display Visibility	285
3.3.5.2	Installed Equipment Performance Requirements	285
3.3.5.2.1	General Performance Requirements	285
3.3.5.2.2	Vertical Path Deviation Display	285
3.3.5.3	Test Procedures for Installed Equipment Performance.	285
3.3.5.3.1	Ground Test Procedures	285
3.3.5.3.1.1	Antenna to Aircraft Navigation Reference Offset	285
3.3.5.3.2	Flight Test Procedures	285
3.3.5.3.2.1	Differential GPS/WAAS Operation.	285
3.3.5.3.2.2	Flight Technical Error	286
3.3.5.3.2.3	Continuity of Navigation Data.	286
3.4	Class Delta-4 Equipment to Support Precision Approach Navigation	286
3.4.1	Installation Requirements	286
3.4.2	Installed Equipment Performance Requirements	286
3.4.3	Test Procedures for Installed Equipment Performance.	286
3.4.3.1	Ground Test Procedures	286
3.4.3.2	Flight Test Procedures.	287
4	OPERATIONAL CHARACTERISTICS	289
4.1	Preface.	289
4.2	Turn-On and Initialization of the WAAS GNSS Airborne Receiving System.	289
4.3	Initial Ground Operations	289
4.4	Take Off and Departure	289
4.5	Turn Maneuvers	290
4.6	En Route	290
4.7	Approach.	290
4.8	Missed Approach	291

APPENDICES

Appendix A—WIDE AREA AUGMENTATION SYSTEM SIGNAL SPECIFICATION

A.1	Introduction	A-1
A.2	Signal Characteristics	A-1
A.2.1	Carrier Frequency	A-1
A.2.2	Spurious Transmissions	A-1
A.2.3	Modulation	A-1
A.2.4	Carrier Phase Noise	A-1
A.2.5	Signal Spectrum	A-1
A.2.6	Signal Characteristics Modified Relative To GPS	A-1
A.2.6.1	Doppler Shift	A-1
A.2.6.2	Carrier Frequency Stability	A-2
A.2.6.3	Polarization	A-2
A.2.6.4	Code/Carrier Frequency Coherence	A-2
A.2.6.5	User Received Signal Levels	A-2
A.2.6.6	Correlation Loss	A-2
A.2.6.7	Maximum Code Phase Deviation	A-3
A.3	WAAS C/A Codes	A-3
A.3.1	Requirements	A-3
A.3.2	Identification of WAAS Codes	A-3
A.3.3	WAAS Codes	A-4
A.3.4	Recommended WAAS/GPS Coder Implementation	A-4
A.4	WAAS Signal Data Contents and Formats	A-6
A.4.1	Introduction	A-6
A.4.2	Principles and Assumptions	A-7
A.4.2.1	Data Rate	A-7
A.4.2.2	Timing	A-7
A.4.2.3	Error Corrections	A-8
A.4.2.4	Tropospheric Model	A-8
A.4.2.5	Residual Tropospheric Error	A-10
A.4.2.6	PRN Masks	A-10
A.4.2.7	Number of Satellites	A-10
A.4.2.8	Issue of Data	A-10
A.4.2.9	Acquisition Information	A-10
A.4.3	Format Summary	A-11
A.4.3.1	Block Format	A-11
A.4.3.2	Block Length and Content	A-11
A.4.3.3	Parity	A-11
A.4.3.4	Preamble	A-12
A.4.4	Messages and Relationships Between Message Types	A-13
A.4.4.1	Do Not Use for Safety Applications Message Type 0	A-15
A.4.4.2	PRN Mask Assignments Message Type 1	A-15
A.4.4.2.1	PRN Mask Transition	A-16
A.4.4.3	Fast Corrections Message Types 2 - 5	A-16
A.4.4.4	Integrity Information Message Type 6	A-18
A.4.4.5	Fast Correction Degradation Factor Message Type 7	A-20
A.4.4.6	Degradation Factors Message Type 10	A-22
A.4.4.7	Long Term Satellite Error Corrections Message Type 25	A-23

A.4.4.8	Mixed Fast Corrections/Long Term Satellite Error Corrections Messages Type 24	A-27
A.4.4.9	Ionospheric Grid Point Masks Message Type 18	A-28
A.4.4.10	Ionospheric Delay Corrections Messages Type 26	A-34
A.4.4.10.1	Pierce Point Location Determination	A-36
A.4.4.10.2	Selection of Ionospheric Grid Points	A-37
A.4.4.10.3	Ionospheric Pierce Point Vertical Delay and Model Variance Interpolation	A-39
A.4.4.10.4	Computing Slant Ionospheric Delay and Ionospheric Model Variance . . .	A-42
A.4.4.11	GEO Navigation Message Type 9	A-43
A.4.4.12	GEO Almanacs Message Type 17	A-44
A.4.4.13	WAAS Service Message Type 27	A-46
A.4.4.13.1	Definition of Regions	A-46
A.4.4.14	Null Message Type 63 and Internal Test Message 62	A-48
A.4.4.15	WAAS Network Time/UTC/GLONASS Time Offset Parameters Message Type 12	A-48
A.4.4.16	Clock-Ephemeris Covariance Matrix Message Type 28	A-49
A.4.5	Modeling the Degradation of Data	A-52
A.4.5.1	Fast and Long-Term Correction Degradation	A-53
A.4.5.1.1	Fast Correction Degradation	A-53
A.4.5.1.2	Range-Rate Correction Degradation	A-54
A.4.5.1.2.1	Range-Rate Correction Degradation — IODF \neq 3	A-54
A.4.5.1.2.2	Range-Rate Correction Degradation — Either IODF = 3	A-54
A.4.5.1.3	Long Term Correction Degradation	A-55
A.4.5.1.3.1	Long Term Correction Degradation — Velocity Code = 1	A-55
A.4.5.1.3.2	Long Term Correction Degradation — Velocity Code = 0	A-55
A.4.5.1.3.3	GEO Navigation Message Degradation	A-56
A.4.5.1.4	Degradation for En Route Through NPA	A-56
A.4.5.2	Degradation of Ionospheric Corrections	A-57
A.4.6	Principles and Rules for the Generation and Use of Data	A-57
A.4.7	Timing	A-58
A.5	References	A-59
Appendix B—STANDARD GPS/WAAS ASSUMPTIONS		
B.1	GPS Constellation	B-1
B.2	WAAS Constellation	B-2
B.3	Selective Availability	B-2
B.4	GPS Satellite Failure	B-2
B.5	GPS Constellation for Availability Analysis	B-2
B.6	Signal Quality Monitoring	B-3
B.6.1	Dead Zones	B-3
B.6.2	False Peaks	B-4
B.6.3	Distortions	B-4
B.6.4	Threat Models	B-4
B.6.4.1	Threat Model A	B-4
B.6.4.2	Threat Model B	B-4
B.6.4.3	Threat Model C	B-4

Appendix C—STANDARD RECEIVED SIGNAL AND INTERFERENCE ENVIRONMENT

C.1	Introduction	C-1
C.2	Operating Interference Environment	C-1
C.2.1	Out-of-Band Interference	C-1
C.2.1.1	Out-of-Band Pulse Interference	C-2
C.2.2	In-Band and Near-Band Interference	C-2
C.2.2.1	In-Band and Near-Band Pulsed Interference	C-3

Appendix D—DATA FORMAT FOR HIGH INTEGRITY INFORMATION TO SUPPORT STRAIGHT AND ADVANCED LANDING APPROACH OPERATIONS

D.1	Introduction	D-1
D.2	Format	D-1
D.2.1	Overall Structure	D-1
D.2.2	Data Block Description	D-1
D.2.3	Data Block Structure	D-1
D.3	Final Approach Segment Data Block	D-2
D.3.1	Final Approach Segment Parameter Definition	D-2
D.3.2	Final Approach Segment Data Table	D-5
D.4	Advanced Procedures Data Blocks	D-5
D.5	CRC Definition	D-5
D.6	Informative Section	D-6
D.6.1	Integrity Protection of Data Blocks	D-6
D.6.2	Approach Path Selection	D-6
D.6.3	Data Block Generation	D-7
D.6.4	Database Formatting and Distribution	D-7
D.6.5	CRC Generation and Decoding	D-7
D.6.6	CRC Selection	D-8
D.6.7	Reference Coordinate System	D-8
D.7	References	D-8

Appendix E—BASELINE WEIGHTED NAVIGATION SOLUTION AND NAVIGATION SYSTEM ERROR ALGORITHMS FOR PRECISION APPROACH

E.1	Introduction	E-1
E.2	Baseline Navigation Solution	E-1
E.3	Baseline Navigation System Error Warning Algorithm	E-2
E.4	References	E-4

Appendix F—VERTICAL NAVIGATION (VNAV)

Appendix G—REQUIREMENTS FOR BAROMETRIC ALTIMETER AIDING

G.1	General	G-1
G.2	Altimeter Aiding with GPS Calibration	G-1
G.2.1	Requirements for Calibration	G-1
G.2.2	Calculation of sbaro	G-2
G.2.3	Actual Use of the Altitude Measurement to Augment GPS	G-3

G.3	Barometric Altimeter Aiding Using Baro-corrected Pressure Altitude	G-3
G.3.1	Requirements for Calibration	G-4
G.3.2	Calculation of σ_{baro}	G-4
G.3.3	Actual Use of the Barometric Altitude Measurement to Augment GPS	G-5
G.3.4	Requirements for Pilot Interaction	G-5
G.4	Test Procedures	G-5
G.5	References	G-6

Appendix H—STANDARD OUTPUT FORMAT

H.1	Introduction	H-1
H.2	GPS Minimum Output and Output Timing	H-1
H.2.1	Minimum GPS/WAAS Output	H-1
H.2.2	Timing	H-3
H.3	Other Desirable GPS Outputs	H-4
H.4	Summary	H-4

Appendix I—EXAMPLE STEP DETECTOR

I.1	Step Detector	I-1
-----	-------------------------	-----

Appendix J—WAAS-BASED PROTECTION LEVELS FOR EN ROUTE THROUGH PRECISION APPROACH MODE

J.1	WAAS Protection Level Equations — General Least Squares Solutions	J-1
J.2	HPLWAAS Parameters	J-2
J.2.1	K	J-2
J.2.2	Variance of Fast and Long Term Correction Residuals	J-2
J.2.3	Variance of Ionospheric Delay	J-3
J.2.4	Variance of Airborne Receiver Errors	J-3
J.2.5	Variance of Tropospheric Errors	J-5
J.3	Rationale for HPL and VPL Parameters	J-5
J.3.1	Selection of K Values	J-5
J.3.2	Rationale for Fast and Long-Term Residuals	J-5
J.3.3	Rationale for Ionospheric Delay Residuals	J-6
J.3.4	Rationale for Receiver Residuals	J-6
J.3.5	Rationale for Tropospheric Residuals	J-6

Appendix K—FAULT DETECTION AND EXCLUSION REFERENCES K-1

Appendix L—THE DIRECT AND INDIRECT GEODETIC PROBLEMS FOR GREAT CIRCLE NAVIGATION

L.1	General	L-1
L.2	Definitions of Terms	L-1
L.3	Nomenclature	L-2
L.4	WGS-84 Parameters (from [5])	L-2
L.5	The Indirect Problem	L-2

L.6	The Direct Problem	L-4
L.7	Validation	L-5
L.8	References	L-7
Appendix M—TEST CONSIDERATIONS		
M.1	Introduction	M-1
M.2	(Initial) Acquisition and Reacquisition Testing Statistical Justification	M-1
M.3	Accuracy Statistical Justification	M-2
M.4	General Simulator Scenario Conditions	M-4
Appendix N—SUMMARY OF REQUIREMENTS		
Appendix O—GLOSSARY AND ACRONYMS		
Appendix P—IONOSPHERIC GRID POINT (IGP) SELECTION FLOWCHARTS		
P.1	Introduction	P-1
Appendix Q—WAAS REQUIREMENTS FOR HELICOPTERS		
Q.1	General	Q-1
Q.2	Non-Numeric Cross-Track Deviation	Q-1
Q.2.1	Non-Numeric Lateral Cross-Track Deviation	Q-1
Q.2.2	Non-Numeric Vertical Deviation	Q-2
Q.2.3	Flight Director and Autopilot Displacement Gains	Q-2
Q.3	Primary Navigation Display	Q-2
Q.3.1	Ground Speed	Q-2
Q.3.2	Active Waypoint Distance	Q-2
Q.4	Alerts and Advisories	Q-3
Q.5	Protection Level	Q-3
Q.5.1	Horizontal Protection Level	Q-3
Q.5.2	Vertical Protection Level	Q-3
Q.5.3	Other Protection Level Considerations	Q-3
Q.6	Autopilot Considerations	Q-3
Q.7	Heliport Approach Databases	Q-3
Q.8	References	Q-3
Appendix R—REQUIREMENTS AND TEST PROCEDURES FOR TIGHTLY INTEGRATED GPS/ INERTIAL SYSTEMS		
R.1	Introduction	R-1
R.2	Requirements	R-1
R.2.1	General FDE Requirements	R-1
R.2.2	Unique Additional Requirements	R-2
R.2.2.1	Assumed Failure Mechanisms	R-2
R.2.2.2	Detection Limit	R-3
R.2.2.3	SatZap	R-4

R.2.2.4	Receiver Clock Aiding	R-4
R.2.2.5	Altitude Aiding	R-4
R.2.2.6	Discriminator Averaging	R-5
R.2.2.7	SA Correlation Effects on Performance	R-6
R.2.2.8	Inertial Coasting Performance Evaluation	R-6
R.3	Tightly Integrated GPS/Inertial Design Concepts	R-7
R.3.1	Integration Methods	R-7
R.3.1.1	Pre Residual (Innovation) Screening	R-8
R.3.1.2	Post Residual Monitoring	R-8
R.3.1.3	Additional Measurement Bias States	R-8
R.3.1.4	Multiple Kalman Filters	R-8
R.3.1.5	Extrapolation Method	R-8
R.3.1.6	Solution Separation Method	R-9
R.3.2	Detection and Exclusion Mechanisms	R-9
R.3.2.1	Transient Detection/Exclusion for 2 nmi/hour Grade Systems	R-9
R.3.2.2	Satellite Redundancy	R-9
R.3.2.3	Integrity Coasting	R-9
R.3.2.4	Gravity/Schuler Coupling	R-9
R.3.2.5	Other Schuler Coupling Related Effects	R-10
R.4	Assumptions	R-10
R.4.1	Signal Error Model	R-10
R.4.2	Satellite Failure Model	R-11
R.5	Validation	R-12
R.5.1	Categorization of Detection and Exclusion Mechanisms	R-12
R.5.1.1	Examples	R-12
R.5.2	Covariance Simulation	R-13
R.5.2.1	Covariance Simulation Methods for Availability Evaluation	R-13
R.5.3	False Detection Probability	R-13
R.5.4	Fault Free Accuracy Performance	R-14
R.5.5	Off-Line Rare Normal Verification	R-14
R.5.6	Off-Line Detection/Exclusion Verification	R-15
R.5.6.1	Detection and Exclusion Mechanism Equivalent to RAIM	R-15
R.5.6.2	Claimed Additional Detection and Exclusion Mechanisms	R-15
R.5.6.2.1	Examples	R-16
R.5.6.2.1.1	RAIM with Transient Detection/Exclusion	R-16
R.5.6.2.1.2	Solution Separation Detection and Exclusion	R-16
R.5.6.2.2	Reference RAIM Models	R-17
R.5.7	On-Line Verification	R-17
R.6	References	R-17

TABLE OF FIGURES

<u>FIGURE 1-1</u>	WAAS ARCHITECTURE	4
<u>FIGURE 1-2</u>	FUNCTIONAL CLASSES	8
<u>FIGURE 1-3</u>	DIAGRAM OF FDE CONDITIONS	14
<u>FIGURE 1-4</u>	MARKOV CHAIN FOR FDE	15
<u>FIGURE 1-5</u>	EXAMPLE FDE EVENTS	16
<u>FIGURE 2-1</u>	AN ACCEPTABLE SATELLITE SELECTION HIERARCHY	34
<u>FIGURE 2-2</u>	SENSITIVITY AND DYNAMIC RANGE CONFIGURATIONS	37
<u>FIGURE 2-3A</u>	RECEIVER BANDWIDTH AND AVERAGE CORRELATOR SPACING FOR E-L ..	

	DISCRIMINATOR TRACKING OF GPS SATELLITES.....	51
<u>FIGURE 2-3B</u>	RECEIVER BANDWIDTH AND AVERAGE CORRELATOR SPACING FOR DD DISCRIMINATOR TRACKING OF GPS SATELLITES.....	52
<u>FIGURE 2-4</u>	TF LEG	75
<u>FIGURE 2-5</u>	RF LEG	76
<u>FIGURE 2-6</u>	DIRECT-TO PATH DEFINITION.....	77
<u>FIGURE 2-7</u>	CF LEG	77
<u>FIGURE 2-8</u>	FLY-BY THEORETICAL TRANSITION AREA.....	80
<u>FIGURE 2-9</u>	FLY-OVER THEORETICAL TRANSITION AREA	80
<u>FIGURE 2-10</u>	WAYPOINT SEQUENCING.....	82
<u>FIGURE 2-11</u>	DEFAULT NAVIGATION MODES	91
<u>FIGURE 2-12</u>	FULL-SCALE DEFLECTION AND DEFINED PATH FOR NORMAL APPROACH (NOT VTF APPROACH).....	98
<u>FIGURE 2-13</u>	FULL SCALE DEFLECTION AND DEFINED PATH FOR VTF APPROACH.....	98
<u>FIGURE 2-14</u>	MISSED APPROACH SCENARIOS.....	99
<u>FIGURE 2-15</u>	FINAL APPROACH SEGMENT DEFINITION	105
<u>FIGURE 2-16</u>	FINAL APPROACH SEGMENT LATERAL DEVIATIONS.....	107
<u>FIGURE 2-17</u>	FINAL APPROACH SEGMENT VERTICAL DEVIATIONS.....	109
<u>FIGURE 2-18</u>	FULL SCALE DEFLECTION AND DEFINED PATH FOR PRECISION APPROACH MODE.....	115
<u>FIGURE 2-19</u>	GENERIC TEST CONFIGURATION FOR BENCH TESTS USING ANTENNA WITH- OUT PREAMPLIFIER.....	139
<u>FIGURE 2-20</u>	GENERIC TEST CONFIGURATION FOR BENCH TESTS USING ANTENNA WITH PREAMPLIFIER	139
<u>FIGURE 2-21</u>	FLIGHT PROFILE FOR FLIGHT PLAN 1.....	256
<u>FIGURE 2-22</u>	FLIGHT PROFILE FOR FLIGHT PLAN 2.....	257
<u>FIGURE 2-23</u>	CROSS-TRACK DEVIATION FOR EN ROUTE AND TERMINAL	261
<u>FIGURE 2-24</u>	CROSS TRACK DEVIATION FOR NPA.....	266
<u>FIGURE 2-25</u>	CROSS-TRACK DEVIATION FOR VECTORED NPA	268
<u>FIGURE A-1</u>	EXPECTED TYPICAL RECEIVED POWER LEVELS.....	A-3
<u>FIGURE A-2</u>	WAAS/GPS CODER IMPLEMENTED WITH SINGLE G2 OUTPUT PLUS PROGRAMMABLE G2 DELAY.....	A-6
<u>FIGURE A-3</u>	WAAS/GPS CODER IMPLEMENTED WITH A PROGRAMMABLE INITIAL G2 STATE	A-6
<u>FIGURE A-4</u>	CONVOLUTIONAL ENCODING.....	A-7
<u>FIGURE A-5</u>	DATA BLOCK FORMAT	A-11
<u>FIGURE A-6</u>	INTERRELATIONSHIPS OF MESSAGES	A-15
<u>FIGURE A-7</u>	EXAMPLE PRN MASK.....	A-16
<u>FIGURE A-8</u>	TYPES 2 - 5 FAST CORRECTIONS MESSAGES FORMAT	A-17
<u>FIGURE A-9</u>	TYPE 6 INTEGRITY MESSAGE FORMAT	A-19
<u>FIGURE A-10</u>	TYPE 7 FAST CORRECTION DEGRADATION FACTOR MESSAGE FORMAT.....	A-21
<u>FIGURE A-11</u>	TYPE 25 LONG TERM SATELLITE ERROR CORRECTIONS VELOCITY CODE = 0	A-24
<u>FIGURE A-12</u>	TYPE 25 LONG TERM SATELLITE ERROR CORRECTIONS VELOCITY CODE = 1	A-26
<u>FIGURE A-13</u>	TYPE 24 MIXED FAST CORRECTION/LONG TERM SATELLITE ERROR CORRECTIONS MESSAGE FORMAT	A-28
<u>FIGURE A-14</u>	EXAMPLE OF AN IONOSPHERIC GRID MASK.....	A-30
<u>FIGURE A-15</u>	PREDEFINED GLOBAL IGP GRID (BANDS 9 AND 10 ARE NOT SHOWN) ..	A-33
<u>FIGURE A-16</u>	TYPE 18 IGP MASK MESSAGE FORMAT.....	A-34
<u>FIGURE A-17</u>	TYPE 26 IONOSPHERIC DELAY CORRECTIONS MESSAGE FORMAT	A-35
<u>FIGURE A-18</u>	IONOSPHERIC PIERCE POINT GEOMETRY	A-37

<u>FIGURE A-19</u>	IONOSPHERIC GRID POINT INTERPOLATION	A-39
<u>FIGURE A-20</u>	FOUR-POINT INTERPOLATION ALGORITHM DEFINITIONS	A-41
<u>FIGURE A-21</u>	THREE-POINT INTERPOLATION ALGORITHM DEFINITIONS	A-42
<u>FIGURE A-22</u>	TYPE 9 GEO NAVIGATION MESSAGE FORMAT	A-43
<u>FIGURE A-23</u>	TYPE 17 GEO ALMANACS MESSAGE FORMAT	A-44
<u>FIGURE A-24</u>	SERVICE MESSAGE TYPE 27	A-47
<u>FIGURE A-25</u>	TYPE 28 CLOCK-EPHEMERIS COVARIANCE MATRIX MESSAGE FORMAT	A-51
<u>FIGURE C-1</u>	INTERFERENCE LEVELS AT THE ANTENNA PORT	C-1
<u>FIGURE C-2</u>	IN-BAND AND NEAR-BAND INTERFERENCE ENVIRONMENTS	C-2
<u>FIGURE D-1</u>	FINAL APPROACH SEGMENT DIAGRAM	D-2
<u>FIGURE E-1</u>	FUNCTIONAL DIAGRAM OF NSE ALGORITHM	E-3
<u>FIGURE H-1</u>	GPS TIMING RELATIONSHIPS	H-3
<u>FIGURE I-1</u>	STEP DETECTOR FLOW DIAGRAM FOR FAULT DETECTION AVAILABLE ..	I-1
<u>FIGURE I-2</u>	STEP DETECTOR FLOW DIAGRAM FOR FAULT DETECTION NOT AVAILABLE	I-2
<u>FIGURE M-1</u>	(RE)ACQUISITION TEST PROBABILITY STATISTICS	M-2
<u>FIGURE M-2</u>	PSEUDORANGE ACCURACY TEST PASS CRITERIA	M-3
<u>FIGURE M-3</u>	PSEUDORANGE ACCURACY TEST PASS PROBABILITY	M-4
<u>FIGURE P-1</u>	GRID POINT SELECTION CRITERIA	P-1
<u>FIGURE P-2</u>	ABS IPP LATITUDE BELOW 60 DEG (5X5)	P-2
<u>FIGURE P-3</u>	ABS IPP LATITUDE BELOW 85 DEG	P-3
<u>FIGURE P-4</u>	ABS IPP LATITUDE BETWEEN 60 & 75 DEG BANDS 9-10	P-4
<u>FIGURE P-5</u>	ABS IPP LATITUDE BETWEEN 75 & 85 DEG	P-5
<u>FIGURE P-6</u>	ABS IPP LATITUDE ABOVE 85 DEG	P-5
<u>FIGURE P-7</u>	ABS IPP LATITUDE BELOW 60 DEG (10X10 SQUARES)	P-6
<u>FIGURE P-8</u>	ABS IPP LATITUDE BELOW 60 DEG (10X10 TRIANGLES)	P-7
<u>FIGURE P-9</u>	ABS IPP LATITUDE BETWEEN 60 & 75 DEG BANDS 9-10	P-8
<u>FIGURE Q-1</u>	LATERAL DISPLAY SCALING	Q-1
<u>FIGURE Q-2</u>	VERTICAL DISPLAY SCALING	Q-2
<u>FIGURE R-1</u>	INFLATION FACTOR	R-6
<u>FIGURE R-2</u>	26 SATELLITE 24 HOUR AUTO-CORRELATION VERSUS RTCA MODEL ..	R-11

TABLE OF TABLES

<u>TABLE 1-1</u>	EQUIPMENT CLASSES AND REQUIREMENTS ORGANIZATION	9
<u>TABLE 2-1</u>	TIMEOUT INTERVALS	28
<u>TABLE 2-2</u>	FAST CORRECTION USER TIME-OUT INTERVAL EVALUATION	29
<u>TABLE 2-3A</u>	GPS TRACKING CONSTRAINTS FOR E-L DLL DISCRIMINATORS	50
<u>TABLE 2-3B</u>	GPS TRACKING CONSTRAINTS FOR DD DLL DISCRIMINATORS	51
<u>TABLE 2-3C</u>	SBAS RANGING FUNCTION TRACKING CONSTRAINTS	52
<u>TABLE 2-4</u>	SAFETY-CRITICAL FUNCTIONS	64
<u>TABLE 2-5</u>	LABELS AND MESSAGES	68
<u>TABLE 2-6</u>	NON-NUMERIC ELECTRICAL OUTPUT REQUIREMENTS	85
<u>TABLE 2-7</u>	NON-NUMERIC DISPLAY REQUIREMENTS	86
<u>TABLE 2-8</u>	DEFINITION OF DEFAULT NAVIGATION MODES	92
<u>TABLE 2-9</u>	SUMMARY OF TYPICAL AUTOMATIC MODE SWITCHING TRANSITIONS ..	92
<u>TABLE 2-10</u>	SUMMARY OF CHANGES IN CROSS-TRACK FULL SCALE DEFLECTION FOR AUTOMATIC MODE SWITCHING	93
<u>TABLE 2-11</u>	EXAMPLE DISPLAY OF LNAV/VNAV WARNINGS	114
<u>TABLE 2-11A</u>	EXAMPLE DISPLAY OF GLS or APV-II WARNINGS	122
<u>TABLE 2-12</u>	CLASS BETA-1 ENVIRONMENTAL TEST REQUIREMENTS	129
<u>TABLE 2-13</u>	CLASS GAMMA-1 ENVIRONMENTAL TEST REQUIREMENTS	130

<u>TABLE 2-14</u>	CLASS BETA-2 ENVIRONMENTAL TEST REQUIREMENTS	131
<u>TABLE 2-15</u>	CLASS GAMMA-2 ENVIRONMENTAL TEST REQUIREMENTS.....	132
<u>TABLE 2-16</u>	CLASS BETA-3 ENVIRONMENTAL TEST REQUIREMENTS	133
<u>TABLE 2-17</u>	CLASS GAMMA-3 ENVIRONMENTAL TEST REQUIREMENTS.....	134
<u>TABLE 2-18</u>	CLASS DELTA-4 ENVIRONMENTAL TEST REQUIREMENTS	135
<u>TABLE 2-19</u>	TEST CROSS REFERENCE MATRIX	141
<u>TABLE 2-20</u>	INITIAL ACQUISITION TIME TEST INTERFERENCE CONDITIONS.....	219
<u>TABLE 2-21</u>	GRADUATED SAMPLING PASS/FAIL CRITERIA	221
<u>TABLE 2-22</u>	REACQUISITION TEST INTERFERENCE CONDITIONS	222
<u>TABLE 2-23</u>	STEADY-STATE ACCURACY TEST BROADBAND INTERFERENCE VALUES.	226
<u>TABLE 2-24</u>	STEADY STATE ACCURACY TEST CWI VALUES.....	226
<u>TABLE 2-25</u>	STEADY-STATE ACCURACY TEST PULSED INTERFERENCE VALUES.....	226
<u>TABLE 2-26</u>	PASS THRESHOLD TABLE	228
<u>TABLE 2-27</u>	RESERVED.....	228
<u>TABLE 2-28</u>	MAXIMUM NUMBER OF OUTCOMES TO OFF-LINE FDE TEST	234
<u>TABLE 2-29</u>	WAYPOINT INFORMATION FOR FIRST FLIGHT PLAN FOR SIMULATED FLIGHT PLAN TEST 1	242
<u>TABLE 2-30</u>	NOT USED	242
<u>TABLE 2-31</u>	WAYPOINT INFORMATION FOR SIMULATED FLIGHT PLAN TEST 2	243
<u>TABLE 2-32</u>	SIMULATED FLIGHT PLAN TEST NUMBER 1	244
<u>TABLE 2-33</u>	SIMULATED FLIGHT PLAN TEST NUMBER 2	251
<u>TABLE 2-34</u>	WAYPOINTS FOR CROSS TRACK DEVIATION BENCH TEST FOR EN ROUTE AND TERMINAL.....	262
<u>TABLE 2-35</u>	TEST SEQUENCE FOR EN ROUTE AND TERMINAL CROSS-TRACK DEVIATION	264
<u>TABLE 2-36</u>	TEST SEQUENCE FOR NPA CROSS TRACK DEVIATION.....	265
<u>TABLE 2-37</u>	TEST SEQUENCE FOR VTF NPA CROSS-TRACK DEVIATION	267
<u>TABLE 2-38</u>	HUMAN FACTORS TEST: CHECKLIST 1. EQUIPMENT USABILITY.....	270
<u>TABLE 2-39</u>	HUMAN FACTORS TEST: CHECKLIST 2. DISPLAY BRIGHTNESS	271
<u>TABLE 2-40</u>	HUMAN FACTORS TEST: CHECKLIST 3. AUDIBLE ALERTS	272
<u>TABLE 2-41</u>	HUMAN FACTORS TEST: CHECKLIST 4. EQUIPMENT CONTROLS.....	273
<u>TABLE 3-1</u>	EQUIPMENT CLASSES AND ORGANIZATION OF SECTION 3	275
<u>TABLE A-1</u>	SBAS RANGING C/A CODES	A-5
<u>TABLE A-2</u>	METEOROLOGICAL PARAMETERS FOR TROPOSPHERIC DELAY	A-9
<u>TABLE A-3</u>	MESSAGE TYPES	A-14
<u>TABLE A-4</u>	PRN MASK ASSIGNMENTS	A-16
<u>TABLE A-5</u>	TYPE 6 INTEGRITY MESSAGE CONTENT.....	A-19
<u>TABLE A-6</u>	EVALUATION OF UDREII	A-20
<u>TABLE A-7</u>	TYPE 7 FAST CORRECTION DEGRADATION FACTOR MESSAGE CONTENTS	A-21
<u>TABLE A-8</u>	FAST CORRECTIONS DEGRADATION FACTOR AND USER TIME-OUT INTERVAL EVALUATION	A-22
<u>TABLE A-9</u>	TYPE 10 DEGRADATION FACTORS	A-23
<u>TABLE A-10</u>	TYPE 25 LONG TERM SATELLITE ERROR CORRECTIONS HALF MESSAGE PARAMETERS WITH VELOCITY CODE OF 0 (POSITION AND CLOCK OFFSET CORRECTIONS ONLY)	A-25
<u>TABLE A-11</u>	TYPE 25 LONG TERM SATELLITE ERROR CORRECTIONS HALF MESSAGE PARAMETERS WITH VELOCITY CODE OF 1 (VELOCITY AND CLOCK DRIFT CORRECTIONS INCLUDED).....	A-26
<u>TABLE A-12</u>	PREDEFINED WORLD-WIDE IGP SPACING — BANDS 0 - 8	A-28
<u>TABLE A-13</u>	PREDEFINED WORLD-WIDE IGP SPACING — BANDS 9 - 10	A-28
<u>TABLE A-14</u>	IONOSPHERIC MASK BANDS	A-31

<u>TABLE A-15</u>	TYPE 18 IGP MASK MESSAGE CONTENTS	A-34
<u>TABLE A-16</u>	IONOSPHERIC DELAY MODEL PARAMETERS FOR MESSAGE TYPE 26	A-35
<u>TABLE A-17</u>	EVALUATION OF GIVE I_1	A-36
<u>TABLE A-18</u>	TYPE 9 GEO NAVIGATION MESSAGE PARAMETERS	A-44
<u>TABLE A-19</u>	TYPE 17 GEO ALMANACS MESSAGE PARAMETERS	A-45
<u>TABLE A-20</u>	TYPE 27 SERVICE MESSAGE PARAMETERS	A-47
<u>TABLE A-21</u>	DUDRE INDICATOR EVALUATION	A-48
<u>TABLE A-22</u>	WAAS NETWORK TIME/UTC PARAMETERS	A-49
<u>TABLE A-23</u>	UTC STANDARD IDENTIFIER	A-49
<u>TABLE A-24</u>	TYPE 28 CLOCK-EPHEMERIS COVARIANCE MATRIX MESSAGE PARAMETERS	A-52
<u>TABLE A-25</u>	MESSAGE CONTENT BROADCAST INTERVALS	A-58
<u>TABLE B-1</u>	OPTIMIZED 24 GPS CONSTELLATION	B-1
<u>TABLE B-2</u>	GPS CONSTELLATION ON DECEMBER 1, 1995 AT 00:00 UTC	B-3
<u>TABLE C-1</u>	OUT-OF-BAND PULSE INTERFERENCE	C-2
<u>TABLE C-2</u>	IN-BAND AND NEAR-BAND INTERFERENCE BANDWIDTH DEFINITIONS . .	C-3
<u>TABLE C-3</u>	IN-BAND AND NEAR-BAND PULSE INTERFERENCE	C-3
<u>TABLE D-1</u>	FINAL APPROACH SEGMENT (FAS)	D-5
<u>TABLE G-1</u>	PRESSURE GRADIENT ERRORS (KNOWN GL)	G-3
<u>TABLE G-2</u>	PRESSURE GRADIENT ERRORS (UNKNOWN GL)	G-3
<u>TABLE H-1</u>	MINIMUM GPS OUTPUT	H-2
<u>TABLE L-1</u>	TEST CASE INPUT	L-6
<u>TABLE L-2</u>	TEST CASE OUTPUT	L-6
<u>TABLE L-3</u>	NUMBER OF ITERATIONS	L-7
<u>TABLE M-1</u>	GRADUATED SAMPLING PASS/FAIL CRITERIA	M-2
<u>TABLE N-1</u>	CLASS BETA AND GAMMA REQUIREMENTS	N-2
<u>TABLE N-2</u>	CLASS GAMMA REQUIREMENTS	N-25
<u>TABLE N-3</u>	CLASS DELTA-4 REQUIREMENTS FOR PRECISION APPROACH OPERATIONS	N-62
<u>TABLE R-1</u>	SUMMARY OF FDE REQUIREMENTS	R-1
<u>TABLE R-2</u>	SUMMARY OF FAILURE TYPE PROBABILITIES	R-3
<u>TABLE R-3</u>	COASTING PERFORMANCE EXAMPLE WITH SSA=33.3 M	R-7
<u>TABLE R-4</u>	EQUIVALENT ALTITUDE ACCURACY	R-10
<u>TABLE R-5</u>	REQUIRED NUMBER OF TRIALS FOR EACH FAILURE MODE	R-16

This page intentionally left blank.

1 PURPOSE AND SCOPE

1.1 Introduction

This document contains minimum operational performance standards (MOPS) for airborne navigation equipment (2D and 3D) using the Global Positioning System (GPS) augmented by the Wide Area Augmentation System (WAAS). Throughout this document, the term “WAAS” is used as a generic reference to Satellite-Based Augmentation Systems (SBAS). These standards are intended to be applicable to other SBAS providers, such as European Geostationary Navigation Overlay Service (EGNOS) and Japan’s Multi-functional Transport Satellite (MTSAT) Satellite -based Augmentation System (MSAS).

In this document, the term “shall” is used to indicate requirements. An approved design should comply with every requirement, which can be assured by inspection, test, analysis, or demonstration. The term “must” is used to identify items which are important but are either duplicated somewhere else in the document as a “shall”, or are considered to be outside the scope of this document. The term “should” is used to denote a recommendation that would improve the WAAS equipment, but does not constitute a requirement.

The standards define minimum performance, functions and features for WAAS-based sensors that provide position information to a multi-sensor system or separate navigation system. They also address WAAS-based Area Navigation (RNAV), and optionally Vertical Navigation (VNAV), equipment to be used for the en route, terminal area, and non-precision approach phases of flight. These standards are based upon a nominal allocation of the aircraft-level requirements in RTCA/DO-236A, *Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation*, accounting for the unique issues associated with WAAS and GNSS navigation service and minimizing the need for pilot training. These standards also define performance, functions and features for equipment that satisfies the requirements for approach procedures with vertical guidance APV and Global Navigation Satellite System (GNSS) Landing System (GLS). The standards cover WAAS-based equipment which is designed to serve combinations of the above phases of flight; updated standards for multi-sensor systems are being developed by RTCA Special Committee 181.

Compliance with these standards by manufacturers, installers and users is recommended as one means of assuring that the equipment will satisfactorily perform its intended functions under conditions encountered in routine aeronautical operations, and will ensure a basic compatibility with the requirements defined in RTCA/DO-236A. Manufacturers and operators who elect to comply directly with the requirements of RTCA/DO-236A as part of an aircraft certification (type certificate or supplemental type certificate) may bypass these RNAV standards, but are not expected to be eligible for a Class Gamma TSO authorization.

The regulatory application of these standards is the responsibility of appropriate government agencies. In the United States, the Federal Aviation Administration (FAA) has published a Technical Standard Order (TSO) for GPS/WAAS equipment to reference the requirements and bench test procedures in Section 2.

The word "equipment", as used in this document, includes all components or units necessary (as determined by the equipment manufacturer or installer) to properly perform its intended function. For example, the airborne "equipment" may include: sensor(s), a computer unit, an input-output unit which interfaces with existing aircraft displays/systems, a control unit, a display, shock mount(s), etc. In the case of this example, all of the foregoing components or units constitute the "equipment". It should not be inferred from this example, however, that all GPS/WAAS navigation equipment will necessarily include all of the foregoing components or units. The particular components of GPS/WAAS equipment will