

RTCA, Inc.
1150 18th St. NW, Suite 910
Washington, D.C. 20036, U.S.A.

**Architecture Recommendations for
Aeronautical Information (AI) and
Meteorological (MET) Data Link Services**

RTCA DO-349
March 18, 2014

Prepared by SC-206
©2014 RTCA, Inc

Copies of this document may be obtained from

RTCA, Inc.
1150 18th St., NW, Suite 910
Washington, D.C. 20036, USA

Telephone: 202-833-9339

Faxsimile: 202-833-9434

Internet: www.rtca.org

Please call RTCA for price and ordering information

FOREWORD

This report was prepared by RTCA Special Committee 206 (SC-206) and approved by the RTCA Program Management Committee (PMC) on March 18, 2014.

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,
- 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.

This Page Intentionally Left Blank

EXECUTIVE SUMMARY

The availability of highly reliable, high-throughput, and low-cost wireless aircraft connectivity is growing rapidly. On the other hand, ground-based technologies and systems have far outstripped airborne capabilities in both speed and sheer breadth of available functionality. Certification and approval techniques for airborne systems and capabilities have remained reactionary to the demand rather than leading the way. In some instances, standards and guidance have been created and/or updated, but overall have not evolved appreciably with the breakneck pace of digital data exchange technology.

These Aeronautical Information Services (AIS) and Meteorological (MET) Services Architecture Delivery Recommendations provide industry supported recommendations that will enable greater flexibility for the review and operational approval of systems delivering AIS and MET data services to aircraft cockpits. The delivery recommendations are built upon those applications and uses described in RTCA DO-340, *Concept of Use (ConUse) for Aeronautical Information Services (AIS) and Meteorological (MET) Data Link Services* and RTCA DO-339, *Aircraft Derived Meteorological Data via Data Link for Wake Vortex Air Traffic Management and Weather Applications Operational Services and Environmental Definition (OSED)*. While these two documents provided the basis for the development of this document, other considerations were included in the development of the recommendations contained herein.

Several of the subjects discussed within this document are considered out of scope to the delivery of AIS and MET data link services to cockpits and aircraft in general; however, this document was developed with the purpose of holistically analyzing all of the issues that could enable or hinder AIS and MET data link services. The analysis revealed four main areas of concern:

- architectural ambiguity;
- information quality;
- cyber security; and
- lack of data link message suitability determination standardization.

This document, while describing these areas of concern and proposing recommended paths to solutions, does not specify the precise manner in which solutions must be defined. The specifics necessary to address these recommendations, in many cases, lie with future efforts. The analysis led to the creation of a set of recommendations detailed in [Section 1.7](#). The recommendations were limited to assessed obstacles to achieving data link services. Further explanation as to the analysis and assessment that allowed the derivation of each recommendation is contained within the relevant sections.

Architecture:

RTCA DO-340 described a clarification of how to think of data link services. That document defined Category 1 and Category 2 data link services. This was an important first step in moving away from earlier concepts of how to differentiate data link services. What it did not provide was the means to apply these new definitions.

- What does it mean practically for a data link service to be classified as Category 1 versus Category 2?
- Is there a difference between a behavior and a required communication performance parameter?
- What functions need to be accomplished for which service?

This document describes a framework that answers the above questions and more. A holistic functional architecture, outlined in Section 3, attempts to capture identified needs. This architecture again does not provide a minimum requirement for all data link systems, but it does provide a structure from which functional choices can be made by implementers, regulators, and standards groups. Included in the architectural discussion are recommendations to achieve flexible development by implementers of data link services. The flexible approach outlined is a recommendation; and if applied correctly, it will allow the greatest amount of innovation, while still allowing for the appropriate amount of regulatory oversight to achieve safe operations.

Information Quality Assurance:

In order to achieve approval for operational use of data link services to aircraft for the purpose of supporting or satisfying the air traffic service function, the information delivered through those services must have some level of assurance as to its quality. The industry and regulatory agencies currently face two challenges to realizing this assurance.

On the one hand, the information delivered to aircraft is largely dependent upon the quality of the information as generated by the source prior to incorporation into the data link service. While various data quality standards exist, there is not a mandated minimum requirement that data producers must abide by for the full breadth of information that is to be dynamically data linked to aircraft in the next generation of aviation.

On the other hand, standards exist to assure the quality of aeronautical data as it moves along the data chain. These standards, while potentially adaptable for information made more contextually relevant delivered via data link, their efficiency for information managed on a working and free flowing basis requires further investigations. A standardized process necessary to achieve either certification or operational approval of the developing high bandwidth data link delivery systems does not currently exist. This creates a situation where the industry has developed or is developing capabilities that can assist in the realization of the RTCA DO-340 described uses, but they languish in complex and ambiguous approval processes that are unique to each effort.

Section 4 describes the situation as it relates to information quality assurance and provides specific and timely recommendations. Without clear regulatory oversight and rigorous attention to achieving quality information origination as well as delivery assurance, Category 1 delivery services as well as the uses that they intend to support will not be achievable in the near term.

Security:

The operational use of AIS and MET data link services introduces concerns related to cyber security threats and vulnerabilities. These security concerns are system-wide, which may impact the overall data link service, including aircraft systems. These concerns need to be addressed through both the aircraft system certification process and the aircraft operational approval process. Central to resolving issues surrounding data, data exchange, and data link security is that it be viewed on an end-to-end basis.

While there are several efforts underway to define systems and data security as it relates to aircraft systems and data link technologies, there continues to be a demand for an overarching security architecture set, which may satisfy the needs for safe operation of aircraft well into the future.

Allocation of Use to Data Link:

Underlying all of the above subjects lays the means to provide, via data link, the data that is the foundation of any data link service. The determination of which data link(s) is suitable to provide services for a given use(s) continues to focus frequently on incumbent safety service defined data links instead of broadening the field to other links for consideration. In turn, this causes delays in implementation, unrealized safety, cost and user benefits and lastly a reduction in vendor competitiveness and opportunity.

To begin to address these shortcomings, Section 6 describes and outlines a repeatable process for determining suitable delivery methods for current and future AIS and MET applications, uses, and data link technologies. This recommended and flexible approach provides a structure by which multiple disparate data link technologies may be comparatively analyzed as potential candidates to provide the specified level of service.

The analysis resulting from this process will inform FAA and industry decisions regarding acceptable delivery methods and the relevant architecture given limited spectrum for specific uses and services today. By standardizing the determination of data links' suitability, the recommended process is expected to have the following benefits: future implementation of services will be shortened, safety will be improved, costs will be reduced, and competition will increase.

This Page Intentionally Blank

TABLE OF CONTENTS

1 INTRODUCTION.....	1
1.1 Purpose.....	1
1.2 Background.....	2
1.3 Scope.....	5
1.3.1 Assumptions.....	8
1.3.2 Disclaimers.....	8
1.4 Document Overview.....	8
1.4.1 Document Organization.....	8
1.5 References.....	9
1.6 Terms.....	13
1.6.1 Glossary.....	13
1.6.2 Abbreviations/Acronyms.....	16
1.7 Summary Recommendations.....	25
2 DATA LINK CONCEPT.....	29
2.1 Concept Intended Uses.....	29
2.1.1 Delivery Services Concepts.....	29
2.1.2 AIS and MET Data Link Use Concepts.....	31
2.1.3 Aircraft Derived MET Data Use Concepts.....	31
2.2 Conceptual Architecture.....	33
3 ARCHITECTURE.....	35
3.1 Existing Architecture Survey.....	35
3.1.1 Survey of Existing Airborne Architecture.....	35
3.1.2 Survey of Existing Ground Architecture.....	36
3.2 Architecture Shortfall.....	37
3.2.1 Lack of and Need for Overarching Guidance.....	37
3.2.2 Architectural High Level Functional Needs.....	38
3.3 Architecture Recommendations for AIS and MET Delivery.....	42
3.3.1 Existing Equipment Architecture.....	42
3.3.2 Functional Architecture.....	42
3.3.2.1 System Description.....	43
3.3.2.2 Functional Depiction.....	48
3.3.3 Category 1 versus Category 2 Delivery Services.....	57
3.3.3.1 Data Link Services: ANSP and Commercial.....	58
3.3.3.2 Uncertainty of the Mapping between Use and Category.....	60
3.3.4 Downlink and Crosslink.....	62
3.3.5 Local Services.....	63
3.3.6 Enterprise Services.....	64

4	INFORMATION QUALITY ASSURANCE	69
4.1	Current Information Quality Process	69
4.2	Information Quality Shortfall	70
4.2.1	AIS	70
4.2.2	MET	71
4.3	Information Quality Recommendations	71
4.3.1	Source Data Quality	71
4.3.2	Data Chain	72
4.3.3	Recommendations	72
5	SECURITY	75
5.1	Current Approach to Security	75
5.1.1	Current Guidance	75
5.1.2	Security Assumptions	76
5.1.2.1	ATS Data Link Service Providers	76
5.1.2.2	Non-Governmental Data Link Service Providers	76
5.2	Security Shortfall	77
5.3	Security Recommendations	77
6	ALLOCATION OF USE TO DATA LINK	79
6.1	Current Methods of Data Link Allocation	79
6.2	Data Link Allocation Shortfall	80
6.3	Data Link Allocation Methodology Recommendation	80
6.3.1	Process Overview	80
6.3.2	Procedure Steps	85
6.3.2.1	Identify Use and Apply to Use Case	85
6.3.2.2	Define Use Case Operational Characteristics	85
6.3.2.2.1	Identify Uplink/Downlink/Crosslink	85
6.3.2.2.2	Identify Service	86
6.3.2.2.3	Identify Mode	87
6.3.2.2.4	Identify Airspace Domain	87
6.3.2.2.5	Identify Geographic Area	88
6.3.2.2.6	Determine the Number of Aircraft	89
6.3.2.2.7	Identify Use Case Performance Requirements	90
6.3.2.3	Determine the Data Links that Align with the Use Case	91
6.3.2.4	Define Messages	92
6.3.2.4.1	Identify Message Size(s)	92
6.3.2.4.2	Identify Rate of Message Generation	93
6.3.2.5	Define Use Case Technical Characteristics	93
6.3.2.5.1	Determine Duration of Use Case	93
6.3.2.5.2	Determine Size of Use Case Volume	94
6.3.2.5.3	Determine Non-Use Case Load on the Data Link	94
6.3.2.6	Data Link Modeling	95

6.3.2.6.1	Introduction.....	95
6.3.2.6.2	Data Link Models Development.....	96
6.3.2.6.3	Simulation Model Outputs.....	97
6.3.2.7	AIS and MET Run Data Link Model.....	98
6.3.2.8	Perform Post-Model Run Processing.....	99
6.3.2.9	Define Qualitative Operational Characteristics	99
6.3.2.9.1	Identify Data Link Approval to Handle Safety Services Data.....	99
6.3.2.9.2	Identify Ability to Interface with Aircraft Systems	100
6.3.2.9.3	Identify Data Link Layer/Multiple Access Scheme.....	100
6.3.2.9.4	Identify Standards/Regulatory Maturity	101
6.3.2.9.5	Identify Data Link Quality of Service Capabilities.....	101
6.3.2.9.6	Identify Legal/Regulatory Restrictions.....	102
6.3.2.10	Evaluate Model Results against Use Case Performance Requirements and Qualitative Considerations.....	102
6.3.2.10.1	Evaluate Model Results Against Use Case Performance Requirements.....	103
6.3.2.10.2	Evaluate Model Results Against Qualitative Considerations	103
6.3.2.11	Develop Recommendations	103
6.3.2.12	Report Results and Recommendations	104
7	PROCESS ANALYSES.....	105
7.1	RTCA DO-339 Aircraft Derived Meteorological Data via Data Link for Wake Vortex, Air Traffic Management, and Weather Applications Service OSED.....	105
7.1.1	Wake-free Arrival Service	105
7.1.1.1	Use Case Description.....	105
7.1.1.2	Results.....	106
7.1.1.3	Data Link Recommendation	106
7.1.2	Characterize the Atmosphere in the Terminal Environment for Wake-free Dynamic Pairwise Separation	106
7.1.2.1	Use Case Description.....	106
7.1.2.2	Results.....	107
7.1.2.3	Data Link Recommendation	108
7.2	RTCA DO-340 Concept of Use (ConUse) for Aeronautical Information Services (AIS) and Meteorological (MET) Data Link Services	108
7.2.1	En Route Hazardous Weather Route Deviation.....	108
7.2.1.1	Use Case Description.....	108
7.2.1.2	Results.....	109
7.2.1.3	Data Link Recommendation	109
7.2.2	Weather Information Provided to Portable and Installed Devices (PaIDs)	109
7.2.2.1	Use Case Description.....	109
7.2.2.2	Results.....	110
7.2.2.3	Data Link Recommendation	111
7.3	Evaluation of Potential 1090ES Support for the RTCA DO-339 Described Data Service.....	111
7.3.1	RTCA DO-339 Data Service Data Link Requirements Analysis	111

7.3.2	Data Link Recommendation	111
APPENDIX A MEMBERSHIP		A-1
APPENDIX B USE CASES APPLIED TO ANALYSIS		B-1
B.1	RTCA DO-339	B-1
B.1.1	Use Case Scenario Analysis Report 1	B-1
B.1.1.1	Analysis Results	B-1
B.1.1.1.1	Methodology	B-1
B.1.1.1.2	Results	B-1
B.1.1.1.3	Recommendations	B-3
B.1.1.2	Use Case	B-5
B.1.1.2.1	Use Case Scenario	B-5
B.1.1.2.2	Use Case Operational Characteristics	B-9
B.1.1.3	Analysis	B-10
B.1.1.3.1	Data Link Qualification	B-10
B.1.1.3.1.1	Data Link(s) Qualified	B-10
B.1.1.3.1.2	Data Link(s) Not Qualified	B-11
B.1.1.3.2	Quantitative Analysis	B-12
B.1.1.3.2.1	Use Case Messages	B-12
B.1.1.3.2.2	Use Case Technical Characteristics	B-13
B.1.1.3.2.3	Simulation Model Results	B-13
B.1.1.3.2.4	Model Results Analysis	B-18
B.1.1.3.3	Qualitative Analysis	B-27
B.1.1.4	Detailed Tabular Results	B-32
B.1.2	Use Case Scenario Analysis Report 2	B-35
B.1.2.1	Analysis Results	B-35
B.1.2.1.1	Methodology	B-35
B.1.2.1.2	Results	B-35
B.1.2.1.3	Recommendations	B-36
B.1.2.2	Use Case	B-38
B.1.2.2.1	Use Case Scenario	B-38
B.1.2.2.2	Use Case Operational Characteristics	B-41
B.1.2.3	Analysis	B-42
B.1.2.3.1	Data Link Qualification	B-42
B.1.2.3.1.1	Data Link(s) Qualified	B-42
B.1.2.3.1.2	Data Link(s) Not Qualified	B-43
B.1.2.3.2	Quantitative Analysis	B-44
B.1.2.3.2.1	Use Case Messages	B-44
B.1.2.3.2.2	Use Case Technical Characteristics	B-45
B.1.2.3.2.3	Simulation Model Results	B-45
B.1.2.3.2.4	Model Results Analysis	B-48
B.1.2.3.2.5	Qualitative Analysis	B-49
B.1.2.4	Detailed Tabular Results	B-50

B.2	RTCA DO-340	B-51
B.2.1	Use Case Scenario Analysis Report 1	B-51
B.2.1.1	Analysis Results	B-52
B.2.1.1.1	Methodology	B-52
B.2.1.1.2	Results	B-52
B.2.1.1.3	Recommendations	B-52
B.2.1.2	Use Case	B-55
B.2.1.2.1	Use Case Scenario	B-55
B.2.1.2.2	Use Case Operational Characteristics	B-56
B.2.1.3	Analysis	B-58
B.2.1.3.1	Data Link Qualification	B-58
B.2.1.3.1.1	Data Link(s) Qualified	B-58
B.2.1.3.1.2	Data Link(s) Not Qualified	B-59
B.2.1.3.2	Quantitative Analysis	B-59
B.2.1.3.2.1	Use Case Messages	B-59
B.2.1.3.2.2	Use Case Technical Characteristics	B-60
B.2.1.3.2.3	Simulation Model Results	B-60
B.2.1.3.2.4	Model Results Analysis	B-65
B.2.1.3.3	Qualitative Analysis	B-67
B.2.1.4	Detailed Tabular Results	B-79
B.2.2	Use Case Scenario Analysis Report 2	B-83
B.2.2.1	Analysis Results	B-83
B.2.2.1.1	Methodology	B-83
B.2.2.1.2	Results	B-83
B.2.2.1.3	Recommendations	B-84
B.2.2.2	Use Case	B-85
B.2.2.2.1	Use Case Scenario	B-85
B.2.2.2.2	Use Case Operational Characteristics	B-86
B.2.2.3	Analysis	B-87
B.2.2.3.1	Data Link Qualification	B-87
B.2.2.3.1.1	Data Link(s) Qualified	B-87
B.2.2.3.1.2	Data Link(s) Not Qualified	B-88
B.2.2.3.2	Quantitative Analysis	B-88
B.2.2.3.2.1	Use Case Messages	B-88
B.2.2.3.2.2	Use Case Technical Characteristics	B-88
B.2.2.3.2.3	Simulation Model Results	B-89
B.2.2.3.2.4	Model Results Analysis	B-89
B.2.2.3.3	Qualitative Analysis	B-89
B.2.2.4	Detailed Tabular Results	B-103
APPENDIX C	TECHNOLOGY PROFILES	C-1

APPENDIX D USE CASE ANALYSIS REPORT TEMPLATE.....	D-1
D.1 Title of Document Use Case is Derived From.....	D-1
D.1.1 Use Case Scenario Analysis Report (n)	D-1
D.1.1.1 Analysis Results.....	D-1
D.1.1.1.1 Methodology	D-1
D.1.1.1.2 Results.....	D-1
D.1.1.1.3 Recommendations.....	D-1
D.1.1.2 Use Case.....	D-1
D.1.1.2.1 Use Case Scenario.....	D-1
D.1.1.2.2 Use Case Operational Characteristics	D-1
D.1.1.3 Analysis.....	D-3
D.1.1.3.1 Data Link Qualification.....	D-3
D.1.1.3.1.1 Data Link(s) Qualified	D-3
D.1.1.3.1.2 Data Link(s) Not Qualified	D-3
D.1.1.3.2 Quantitative Analysis	D-4
D.1.1.3.2.1 Use Case Messages	D-4
D.1.1.3.2.2 Use Case Technical Characteristics	D-4
D.1.1.3.2.3 Simulation Model Results	D-5
D.1.1.3.2.4 Model Results Analysis.....	D-6
D.1.1.3.3 Qualitative Analysis	D-9
D.1.1.4 Detailed Tabular Results.....	D-11
APPENDIX E QUALITATIVE METRICS DESCRIPTION	E-1
E.1 Quality of Service.....	E-1
APPENDIX F DESCRIPTION QUANTITATIVE MODELS.....	F-1
F.1 Description of SATCOM Model for Downlink Use Case Analysis.....	F-1
F.1.1 Introduction.....	F-1
F.1.2 SATCOM Model Description, Parameters, and Assumptions for Study 1	F-2
F.1.3 Methodology Used to Compute Simulation Results.....	F-6
F.1.4 Model Use for Additional Simulation Studies.....	F-9
F.2 Terrestrial Air-to-Ground Model for Downlink Use Case Analysis.....	F-9
F.2.1 Introduction.....	F-9
F.2.2 CDMA2000 EvDO Model Description, Parameters, and Assumptions for Study 2	F-10
F.2.3 Approach Used to Compute Simulation Results	F-16
F.3 Description of SATCOM Model for Uplink Use Case Analysis.....	F-20
F.3.1 Introduction.....	F-20
F.3.2 Contract Mode Implementation in the SATCOM Model	F-21
F.3.3 SATCOM Model RF Parameters and Assumptions for Study 3	F-24
F.3.4 Methodology Used to Compute Simulation Results.....	F-28

APPENDIX G POTENTIAL WAKE VORTEX/AIR TRAFFIC MANAGEMENT/ METEOROLOGICAL SUPPORT BY 1090ES STUDY	G-1
G.1 Introduction.....	G-1
G.1.1 Alternatives and Objectives	G-1
G.1.2 Alternatives Analysis Approach	G-2
G.1.2.1 Wake Vortex/Air Traffic Management/Meteorology Alternatives and Requirements	G-2
G.1.2.2 Broadcast of Additional Wake Vortex/Air Traffic Management/Meteorology Messages	G-2
G.1.2.3 Interleaved Air Reference Velocity	G-3
G.1.3 Appendix G Overview	G-3
G.2 Alternatives Descriptions and Functional Requirements	G-4
G.2.1 Wake Vortex/Air Traffic Management/Meteorology Evaluation Criteria	G-4
G.2.2 Wake Vortex/Air Traffic Management/Meteorology Impact on Automatic Dependent Surveillance-Broadcast Evaluation Criteria.....	G-7
G.2.2.1 Meteorology Formats Increase in Fruit Rate.....	G-7
G.2.2.2 Interleaved Air Reference Velocity Increase in Required Message Decode Probability	G-8
G.2.3 Automatic Dependent Surveillance-Broadcast State Vector Update Requirements	G-13
G.2.4 Summary of Alternatives Evaluation Criteria.....	G-17
G.3 Co-Channel Interference Environment and MITRE Model Performance Validation.....	G-17
G.3.1 General Considerations	G-17
G.3.2 MITRE Model and Fruit Distribution Validation	G-18
G.3.3 Receiver Decoder Validation	G-25
G.3.4 Model Validation Summary	G-31
G.4 Wake Vortex/Air Traffic Management/Meteorology Alternatives Evaluations	G-31
G.4.1 2020 Baseline Scenario Interference.....	G-32
G.4.1.1 Interleaved Air Reference Velocity Wake Vortex Alternative	G-32
G.4.1.2 Additional Meteorology Format Message Broadcasts	G-33
G.4.2 2020 Baseline Interference with Traffic Growth Factors.....	G-34
G.4.2.1 Growth Factor 2 Scenario	G-34
G.4.2.2 Growth Factor 3 Scenario	G-36
APPENDIX H FUNCTIONAL DECOMPOSITION OF THE AIS AND MET RECOMMENDED ARCHITECTURE.....	H-1
H.1 Ground Data Link Processor Function.....	H-2
H.1.1 Ground Data Link Management.....	H-6
H.1.1.1 Manage Ground Communications	H-12
H.1.2 Ground Data Link Processor.....	H-17
H.1.2.1 Prepare Data for Transmission.....	H-24
H.2 Onboard Data Link Processor Function.....	H-29
H.2.1.1 Manage Onboard Communications.....	H-36
H.3 Functional Decomposition Tree.....	H-46

APPENDIX I	CURRENT QUALITY PROCESSES.....	I-1
I.1	AIS.....	I-1
I.2	MET.....	I-5
I.2.1	MET Quality Verification.....	I-6
I.2.1.1	MET Observations.....	I-7
I.2.1.2	MET Analysis Products.....	I-8
I.2.1.3	MET Forecast Products.....	I-8
I.2.2	MET Reporting.....	I-9
I.2.3	Current MET QA User Guidance.....	I-9
I.2.3.1	FAA Aeronautical Information Manual.....	I-9
I.2.3.2	FAA Order 8900.1 – Flight Standards Information Management System (FSIMS).....	I-9
I.2.3.3	RTCA DO-267A – Minimum Aviation System Performance Standards (MASPS) for Flight Information Services-Broadcast (FIS-B) Data Link.....	I-9
I.2.3.4	WMO-8 – Guide to Meteorological Instruments and Methods of Observation.....	I-9

TABLE OF FIGURES

Figure 1-1	SC-206 scope.....	6
Figure 2-1	AIS and MET services physical architecture (notional) [56].....	33
Figure 3-1	Subset of the physical architecture with interface nodes.....	36
Figure 3-2	Logical depiction of systems and interfaces.....	44
Figure 3-3	The functions of AIS and MET data link services.....	49
Figure 3-4	ATS function.....	57
Figure 3-5	Notional crosslink systems architecture.....	63
Figure 6-1	Alternative data link recommendation analysis process.....	82
Figure 6-2	Decomposition – Define Use Case Operational Characteristics.....	83
Figure 6-3	Decomposition – Define Messages and Define Use Case Scenario Technical Characteristics.....	84
Figure 6-4	Decomposition – Define Qualitative Operational Characteristics.....	84
Figure 6-5	Example diagram for aircraft counts and loading for an arrival-based use case.....	90
Figure 6-6	OPNET wireless pipeline stages.....	97
Figure B-1	Service volume with runways for EWR, John F. Kennedy International Airport (JFK), La Guardia Airport (LGA), and Teterboro Airport (TEB).....	B-7
Figure B-2	Service volume with dimensions.....	B-8
Figure B-3	Service volume with runways and dimensions.....	B-8
Figure B-4	Volume characterization.....	B-9
Figure B-5	Volume characterization.....	B-41
Figure B-6	Use case service volume with dimensions.....	B-56
Figure F-1	Illustration of the SATCOM geometry for Study 1.....	F-2
Figure F-2	Illustration of SATCOM links as Ku-band.....	F-3
Figure F-3	Illustration of CDMA concepts for A/G communications.....	F-11
Figure F-4	Hexagonal cell structure in a 2-D plane.....	F-13

Figure F-5 Geographical area and generic base station configuration used for Study 2.....	F-14
Figure F-6 Message flow diagram for uplink use case	F-22
Figure F-7 Message time sequence diagram for uplink use case.....	F-23
Figure F-8 Illustration of the SATCOM geometry for Study 3	F-24
Figure G-1 Wake/ATM/MET update interval requirements versus air-air separation	G-4
Figure G-2 Required probability of message decode for an interval update at CL = 95% vs. number of tries per interval	G-5
Figure G-3 Required message decode probabilities for proposed Wake/ATM/MET broadcast rates and 95% CL update intervals vs. separation range.....	G-6
Figure G-4 Required message decode probabilities for twice the MET Format 1 broadcast rate (or 0.2 mess/sec) and 95% CL update intervals vs. separation range.....	G-6
Figure G-5 Required message decode probabilities for a MET Format 1 broadcast rate of 0.33 mess/sec and 95% CL update intervals vs. separation range	G-7
Figure G-6 1090ES message broadcast rates and report assemble requirements	G-9
Figure G-7 95% probability of SV update within m seconds vs. single message decode probability for $n_v = 2$ mess/sec and $m = 1, 2,$ and 3 seconds.....	G-10
Figure G-8 95% probability of SV update within m seconds vs. single message decode probability for $n_v = 1.67$ mess/sec and $m = 1, 2,$ and 3 seconds.....	G-12
Figure G-9 State vector update intervals required by RTCA DO-338.....	G-13
Figure G-10 Probability of message decode for $m = 1, 2,$ and 3 sec required to meet the SV update interval at 95% probability.....	G-14
Figure G-11 Probability of message decode versus range for the RTCA DO-338 compliant state vector updates for the normal 1090ES case with $n_v = 2$ mess/sec.....	G-15
Figure G-12 Probability of message decode versus range for the RTCA DO-338 compliant state vector updates for the ARV interleaved case with $n_v = 1.67$ mess/sec	G-16
Figure G-13 Measured and modeled radial traffic distribution.....	G-19
Figure G-14 Altitude Distribution Model Fit Compared with WJHTC July 2007 Test Flight Measured Distribution	G-20
Figure G-15 Traffic limitations due to LOS and link signal levels and variations	G-21
Figure G-16 Comparisons of modeled and flight test measured fruit distributions	G-23
Figure G-17 Mode-S fruit from airport surface aircraft in New York area	G-24
Figure G-18 Comparisons of measured and modeled bottom antenna Mode-S fruit distributions at two distances from the NY area airports.....	G-25
Figure G-19 Message Success Rate vs. Received Signal Level for an A3 Receiver in the High Interference Environment for Each Type of Interference	G-26
Figure G-20 Comparison of MITRE decoder model with high fruit rate WJHTC bench measurements ..	G-27
Figure G-21 MITRE receiver/decoder model total performance in high fruit environment.....	G-28
Figure G-22 Message success rate vs. received signal level for an A3 receiver in high and very high interference environments.....	G-29

Figure G-23 Comparison of MITRE decoder model with very high fruit rate WJHTC bench measurements.....	G-30
Figure G-24 Model estimated probability of decode in 2011 flight test interference environment compared with WJHTC measured values.....	G-31
Figure G-25 Baseline 2020 probability of ES message decode vs. range compared with minimum decode probabilities for a SV update with 1, 2, and 3 second velocity lags	G-33
Figure G-26 Baseline 2020 probability of ES message decode vs. range with MET format broadcast compared with minimum decode probabilities for a SV update with 1, 2, and 3 second velocity lags..	G-34
Figure G-27 Baseline 2020 with GF = 2 probability of ES message decode vs. range compared with minimum decode probabilities for a SV update with 1, 2, and 3 second velocity lags.....	G-35
Figure G-28 Baseline 2020 with GF = 2 probability of ES message decode vs. range with MET format broadcast compared with minimum decode probabilities for a SV update.....	G-36
Figure G-29 Baseline 2020 with GF = 3 probability of ES message decode vs. range compared with minimum decode probabilities for a SV update with 1, 2, and 3 second velocity lags.....	G-37
Figure H-1 Decomposition of Function <i>1.0 Provide Ground Data Link Processor Function</i>	H-3
Figure H-2 Decomposition of Function <i>1.1 Provide Ground Data Link Management</i>	H-8
Figure H-3 Decomposition of function <i>1.1.1 Manage Ground Communications</i>	H-13
Figure H-4 Decomposition of function <i>1.2 Provide Ground Data Link Processing</i>	H-18
Figure H-5 Decomposition of function <i>1.2.1 Prepare Data for Transmission</i>	H-25
Figure H-6 Decomposition of function <i>3.0 Provide Onboard Data Link Processor Function</i>	H-30
Figure H-7 Decomposition of function <i>3.1 Provide Onboard Data Link Management</i>	H-34
Figure H-8 Decomposition of function <i>3.1.1 Manage Onboard Communications</i>	H-38
Figure H-9 Decomposition of function <i>3.2 Provide Onboard Data Link Processing</i>	H-41
Figure H-10 Decomposition tree.....	H-47
Figure H-11 GDLPF functional decomposition tree.....	H-48
Figure H-12 ODLPF Functional decomposition tree.....	H-49
Figure I-1 Aeronautical chain and industry standards	I-4

TABLE OF TABLES

Table 1-1 Glossary terms	13
Table 1-2 Abbreviations and acronyms	16
Table 1-3 Summary architecture recommendations	25
Table 3-1 Functional needs.....	38
Table 3-2 System nodes and entities descriptions.....	45
Table 3-3 Describes the functions of AIS and MET data link services	50
Table 3-4 Describes the data flow relationships with the GDLPF.....	51
Table 3-5 Describes the data flow relationships with the ODLPF.....	53
Table 3-6 Aggregate data flows	54
Table 6-1 Example QoS capability checklist.....	102
Table B-1 Use case operational characteristics for the use case in the use case scenario.....	B-9
Table B-2 Data links qualified for the use case	B-11

Table B-3 Data links not qualified for the use case	B-11
Table B-4 Use case messages	B-12
Table B-5 Use case technical characteristics for the use case	B-13
Table B-6 Simulation model results for the use case	B-14
Table B-7 Model results analysis for Ku-band GEO	B-18
Table B-8 Model results analysis for Airborne 3G CDMA2000 EvDO Rev. A	B-22
Table B-9 Qualitative analysis for Ku-band GEO	B-27
Table B-10 Qualitative analysis for 1090ES.....	B-28
Table B-11 Qualitative analysis for UAT/978.....	B-29
Table B-12 Qualitative analysis for Airborne 3G CDMA/EvDO Rev. A	B-29
Table B-13 Qualitative analysis for Airborne 3G CDMA/EvDO Rev. B ATG-4	B-30
Table B-14 Qualitative analysis for Ka-band GEO	B-31
Table B-15 Detailed tabular results	B-33
Table B-16 Use case operational characteristics for the use case in the use case scenario.....	B-41
Table B-17 Data links qualified for the use case	B-42
Table B-18 Data links not qualified for the use case	B-43
Table B-19 Use case messages	B-44
Table B-20 Use case technical characteristics for the use case.....	B-45
Table B-21 Airborne steady state conditions.....	B-46
Table B-22 Airborne steady state conditions.....	B-47
Table B-23 Qualitative analysis for 1090ES.....	B-49
Table B-24 Qualitative analysis for UAT/978.....	B-49
Table B-25 Detailed tabular results	B-50
Table B-26 Use case operational characteristics for the use case	B-57
Table B-27 Data links qualified for the use case	B-58
Table B-28 Data links not qualified for the use case	B-59
Table B-29 Use case messages	B-59
Table B-30 Use case technical characteristics for the use case.....	B-60
Table B-31 Simulation model results for the use case.....	B-61
Table B-32 Model results analysis for Ku-Band GEO	B-65
Table B-33 Qualitative analysis for Ku-band GEO	B-68
Table B-34 Qualitative analysis for VDL Mode 2 (ACARS).....	B-69
Table B-35 Qualitative analysis for VDL Mode 2 (ATN).....	B-70
Table B-36 Qualitative analysis for Airborne 3G CDMA/EvDO Rev. A	B-71
Table B-37 Qualitative analysis for Airborne 3G CDMA/EvDO Rev. B ATG-4	B-71
Table B-38 Qualitative analysis for L-band GEO (ClassicAero)	B-72
Table B-39 Qualitative analysis for L-band GEO (Swiftbroadband)	B-73
Table B-40 Qualitative analysis for L-band GEO (Swift64)	B-74
Table B-41 Qualitative analysis for L-band LEO	B-75
Table B-42 Qualitative analysis for Ka-band GEO	B-75
Table B-43 Qualitative analysis for VDL Mode 0.....	B-76

Table B-44 Qualitative analysis for UAT/978.....	B-77
Table B-45 Qualitative analysis for 1090ES.....	B-78
Table B-46 Qualitative analysis for GBAS/GRAS VDB	B-79
Table B-47 Detailed tabular results	B-80
Table B-48 Use case operational characteristics for the use case.....	B-86
Table B-49 Data links qualified for the use case	B-87
Table B-50 Data links not qualified for the use case	B-88
Table B-51 Qualitative analysis for VDL Mode 0.....	B-89
Table B-52 Qualitative analysis for VDL Mode 2 (ACARS).....	B-90
Table B-53 Qualitative analysis for VDL Mode 2 (ATN).....	B-90
Table B-54 Qualitative analysis for HFDL.....	B-91
Table B-55 Qualitative analysis for Airborne 3G CDMA-EvDO Rev. A	B-92
Table B-56 Qualitative analysis for Airborne 3G CDMA/EvDO Rev. B ATG-4	B-93
Table B-57 Qualitative analysis for GPRS/EvDO	B-94
Table B-58 Qualitative analysis for LTE Advanced (4G)	B-94
Table B-59 Qualitative analysis for AeroMACS	B-95
Table B-60 Qualitative analysis for IEEE 802.11 b/g.....	B-96
Table B-61 Qualitative analysis for IEEE 802.11 a/n.....	B-97
Table B-62 Qualitative analysis for L-band GEO (ClassicAero)	B-98
Table B-63 Qualitative analysis for L-band GEO (Swift64)	B-99
Table B-64 Qualitative analysis for L-band GEO (SwiftBroadband).....	B-99
Table B-65 Qualitative analysis for L-band LEO	B-100
Table B-66 Qualitative analysis for Ku-band GEO	B-101
Table B-67 Qualitative analysis for Ka-band GEO	B-102
Table B-68 Detailed tabular results	B-104
Table C-1 Technology profiles	C-1
Table D-1 Use case operational characteristics for the use case.....	D-2
Table D-2 Data links qualified for the use case	D-3
Table D-3 Data links not qualified for the use case	D-3
Table D-4 Use case messages	D-4
Table D-5 Use case technical characteristics for the use case	D-5
Table D-6 Simulation model results for the use case.....	D-5
Table D-7 Model results analysis for data link (n)	D-7
Table D-8 Qualitative analysis for data link (n).....	D-10
Table D-9 Detailed tabular results	D-11
Table F-1 Generic SATCOM forward link parameters for Study 1	F-4
Table F-2 Generic SATCOM return link parameters for Study 1.....	F-5
Table F-3 Generic CDMA2000 EvDO RF Parameters for Study 2.....	F-15
Table F-4 Generic SATCOM forward link parameters for Study 3	F-25
Table F-5 Generic SATCOM return link parameters for Study 3.....	F-26
Table G-1 Wake/ATM/MET broadcast rates and required coverage	G-2

Table H-1 Describes the system functions performed in <i>1.0 Provide Ground Data Link Processor Function</i>	H-4
Table H-2 Describes the data flow relationships with the GDLPF.....	H-4
Table H-3 Describes the system functions performed in <i>1.1 Provide Ground Data Link Management</i> ..	H-6
Table H-4 Describes the data flow relationships within the GDLM and its sub-functions with the GDLP	H-9
Table H-5 Describes the system functions performed in <i>1.1.1 Manage Ground Communications</i>	H-14
Table H-6 Describes the data flow relationships within the Manage Ground Communications and its sub-functions with the GDLP	H-14
Table H-7 Describes the system functions performed in <i>1.2 Provide Ground Data Link Processing</i> ...	H-19
Table H-8 Describes the data flow relationships within the GDLP and its sub-functions with the GDLM	H-20
Table H-9 Describes the system functions performed in <i>1.2.1 Prepare Data for Transmission</i>	H-26
Table H-10 Describes the data flow relationships within the Prepare Data for Transmission and its sub-functions with the GDLM.....	H-27
Table H-11 Describes the system functions performed in <i>3.0 Provide Onboard Data Link Processor Function</i>	H-29
Table H-12 Describes the data flow relationships with the ODLPF.....	H-31
Table H-13 Describes the system functions performed in <i>3.1 Provide Onboard Data Link Management</i>	H-32
Table H-14 Describes the data flow relationships within the ODLM and its sub-functions with the ODLP	H-35
Table H-15 Describes the system functions performed in <i>3.1.1 Manage Onboard Communications</i>	H-37
Table H-16 Describes the data flow relationships within the Manage Onboard Communications and its sub-functions with the ODLP	H-39
Table H-17 Describes the system functions performed in <i>3.2 Provide Onboard Data Link Processing</i>	H-42
Table H-18 Describes the data flow relationships within the ODLP and its sub-functions with the ODLM	H-43
Table I-1 AI industry standards	I-2

This Page Intentionally Left Blank

1 INTRODUCTION

This Aeronautical Information Services (AIS) and Meteorological (MET) Services Delivery Architecture Recommendations document was developed by RTCA Special Committee (SC-206). The document contains an initial set of industry supported delivery method recommendations for those applications and uses described in RTCA document DO-340, *Concept of Use (ConUse) for Aeronautical Information Services (AIS) and Meteorological (MET) Data Link Services*. A further service defined in RTCA DO-339, *Aircraft Derived Meteorological Data via Data Link for Wake Vortex, Air Traffic Management and Weather Applications Operational Services and Environmental Definition (OSED)* is included in the recommendations. These recommendations cover architectural, information sourcing, security, and allocation processes. The analyses resulting from this process will support the Federal Aviation Administration (FAA) and industry decisions regarding acceptable delivery methods and the relevant architecture given limited spectrum for specific uses and services.

This document has been developed to support the data communications needs of future Air Traffic Management (ATM) concepts (e.g., Next Generation Air Transportation System (NextGen) and potentially provides input for future efforts by the Single European Sky Air Traffic Management Research (SESAR) initiatives). A key objective of these future ATM concepts is to establish the aircraft as a primary participant in collaborative decision making (CDM), and in some cases, establish airspace regions for autonomous operations where the aircraft is primarily responsible for safe separation from other traffic, wake turbulence, weather, and designated/restricted airspace. Timely availability of high quality and reliable electronic AIS and MET information services are necessary to support these global ATM concepts.

1.1 Purpose

This document is to be used by multiple audiences for several purposes: approval authorities and non-regulators. Approval authority entities are the civil or military authorities that authorize the use and/or installation of Data Link Services as defined by RTCA DO-308/European Organisation for Civil Aviation Equipment (EUROCAE) European Document ED-151. The approval authority entity in the United States (U.S.) is the FAA, more specifically the Aviation Safety Services organization within the FAA, which includes Flight Standards Services and Aircraft Certification Services. This document is expected to be used as a decision support document for policy decisions and recommended guidance to FAA for approving AIS and MET data link architectures and systems.

Additionally, this document is being constructed with further standards work in mind. Similar efforts to define, refine, and constrain data delivery to airborne vehicles could