W O R L D   M E T E O R O L O G I C A L   O R G A N I Z A T I O N

COMMISSION FOR BASIC SYSTEMS

OPAG ON INTEGRATED OBSERVING SYSTEMS

EXPERT TEAM ON AIRCRAFT BASED OBSERVING SYSTEMS SUB-GROUP MEETING ON WIGOS REGULATORY MATERIAL

Geneva, Switzerland

2-5 December 2014

FINAL REPORT

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AGENDA

1. Opening and Organization of the Session

2. Revision of Preparatory Work of the ET-ABO Sub-Group on Regulatory Material

3. Presentation of Draft Regulatory Material

3.1 Proposals for Update to the Manual on WIGOS

3.2 Proposals for Update to the Guide to WIGOS

3.3 Proposal for Guidance on AMDAR Optimisation

3.4 Proposal for Guidance on AMDAR Software Development

4. Revision of Draft Regulatory Material

5. Any Other Business

6. Final Report of the Session

GENERAL SUMMARY

1 OPENING AND ORGANIZATION OF THE SESSION

The WMO Commission for Basic Systems (CBS) Expert Team on Aircraft Based Observing Systems (ET-ABO), Sub-Group on WIGOS Regulatory Material (SG-RM) Meeting opened at 9:30am on 2 December 2014 in Geneva, Switzerland by the Chair of ET-ABO and of the Meeting, Mr Frank Grooters. The Participants List is provided within Annex I.

Dr Miroslav Ondras welcomed participants on behalf of the WMO Secretariat and thanked them for their input to the work of the Sub-Group in the lead up to the meeting. He informed the meeting about the status of the WMO regulatory material and advised that regulations and guidance should be focused on updating and improving the relevant sections of WMO-No. 488, Manual on the GOS (the Manual), and WMO-No. 544, Guide to the GOS (the Guide). The meeting was also advised that materials that were required to provide a standard for observing systems, such as the AMDAR Onboard Software Functional Requirements Specification (AOSFRS) might be added to the Guide to the GOS and referenced from the Manual.

The Chair outlined the provisional agenda (Document 1.2 of the document plan for the meeting), provisional meeting schedule (Document 1.3) and working arrangements for the meeting, which were agreed to by the meeting participants without change. It was agreed that a large component of the meeting would be spent working in drafting teams, actively working on the drafting of new and improved regulations that would be consolidated within the final report of the meeting, after which ET-ABO would assume responsibility for revision, refinement and eventual submission of the resulting regulatory materials to CBS through the Implementation and Coordination Team on Integrated Observing Systems (ICT-IOS) and the CBS Inter-Programme Expert Team on WIGOS Framework Implementation Matters (IPET-WIFI).

2 REVISION OF PREPARATORY WORK OF THE ET-SBO SUB-GROUP ON REGULATORY MATERIAL

The Chair provided a brief outline of Document 2 of the meeting Document Plan, in which the approach that the SG-RM had taken to the development of the current draft of section 3.4 of the Guide to the GOS, Aircraft Meteorological Stations, was explained. The SG-RM was appointed by ET-ABO to undertake Task 28 of the ET-ABO work plan, Revision of AMDAR Regulatory Material in WIGOS Context.

The Meeting was informed that the SG-RM had met several times by teleconference in the lead-up to this meeting and had developed a structural framework for the regulatory material, a basic policy for the inclusion of materials and assigned roles to SG-RM members for compilation of initial draft material. In the process of deliberating over text and material for inclusion in the regulatory material, the SG-RM had taken into consideration several existing manuals, guides and technical documents, including:

- The existing text in the Manual on the GOS (WMO-No. 544) and the Guide to the GOS (WMO No. 488)
- The CIMO Guide (WMO-No. 8)
- The AMDAR Reference Manual (WMO-NO. 958)
- WMO Technical Regulations (WMO-No. 49, Volume II, Meteorological Service for International Air Navigation)
- WIGOS Technical Reports
- CIMO IOM Reports
- Various other manuals and guides associated with the World Weather Watch Programme

3 PRESENTATION OF DRAFT REGULATORY MATERIAL

The Chair and the participants presented the Meeting with a summary of the documents and regulatory material that had been compiled in the lead-up to the meeting and advised on how best to utilise the materials in the drafting process to be undertaken.

3.1 Proposals for Update to the Manual on WIGOS

Dr Jitze van der Meulen presented to the Sub-Group an outline of the various materials and documents that had been considered in formulating the proposed structure and content of the guidance material that had been compiled in the lead up to the meeting. This structure, presented in Attachment 1 of Document 2 of the document plan for the meeting, was to be considered as the starting point and a basis for formulating a structure for the regulatory content of the relevant section (2.5 Aircraft Meteorological Stations) of the Manual on the GOS.

The SG-RM agreed that, as for the material for the Guide, the structure of the aircraft-based observations section in the Manual should be consistent with the structure and the content of the draft Manual on WIGOS. It was agreed that the meeting should first revise and consolidate the guidance material and then proceed to developing regulations for the Manual in the light of that more detailed content.

3.2 Proposals for Update to the Guide to WIGOS

Mr Stig Carlberg presented Document 3.2 of the document plan for the meeting to the Sub-Group, which outlined the current status of the guidance material that had been drafted prior to the meeting based on the structure developed, as described above in item 3.1.

While there was still considerable work to do to finalise the draft guidance material, significant progress had been made by the Sub-Group and an already mature and lengthy draft was presented within Annex 1 to Document 3.2.

The meeting was informed that several aspects of the guidance required particular attention including:

- The use of terminology related to quality management and consistent with ISO 9000, the WMO Quality Management Framework and the section 2.6 of the Manual on WIGOS.
- The balance between text in the body of the document and the use of annexes and attachments. In particular, care should be taken that adequate explanation and information was provided within the main part of the Guide, while more technical and detailed material related to specific aspects might be considered for inclusion within attachments to the Guide.
- Ideally, the text in the Guide should be comprehensive enough to give the reader a good overview and understanding of aircraft-based observations and their role and benefit as a product from the observing systems that support WMO Programmes.

3.3 Proposal for Guidance on AMDAR Optimisation

Dr Douglas Body provided a summary of the work that had been done in drafting guidance in relation to AMDAR ground-based data optimization. The current draft was provided within Document 3.3 of the document plan for the meeting. It was agreed that the draft was well advanced and would likely be most usefully published as a separate WIGOS technical report that was referenced from the Guide. The document was to be reviewed by Dr Axel Hoff during the meeting, with an updated draft to be provided as an annex to the final report of the meeting.

3.4 Proposal for Guidance on AMDAR Software Development

Dr Axel Hoff provided a summary of the status of the guidance material that had been developed in the lead up to the meeting in relation to AMDAR software development. The current draft was provided within Document 3.4 of the document plan for the meeting. The document was to be reviewed during the meeting, with an updated draft to be provided as an annex to the final report of the meeting. Consideration should be given to publishing the document as a WIGOS technical report.

4 REVISION OF DRAFT REGULATORY MATERIAL

The SG-RM worked diligently on refining the guidance materials in both plenary and individually throughout the meeting. This work resulted in significantly improved drafts of the four items of regulatory material provided in the annexes to this report:

Annex II: Proposed draft guidance to be included in Section 3.4 of the Guide to the GOS.

Annex III: Proposed draft regulations to be included in Section 2.5 of the Manual on the GOS.

Annex IV: Draft of Guidance on AMDAR Software Development.

Annex V: Draft of Guidance on AMDAR Observing System Data Optimisation.

The agreed actions related to the further refinement, review and approval of the draft material are provided in section 6 below.

5 ANY OTHER BUSINESS

No additional business was identified for discussion or action.

6 FINAL REPORT OF THE SESSION

The Meeting agreed on the following actions and outcomes of the meeting:

1. The Final Report of the meeting should contain the final versions of the four draft documents. [Secretariat]
2. The SG-RM to meet via WebEx in January to develop a consolidated plan for finalisation of the regulatory material prior to submission to CBS through ET-ABO and ICT-IOS. [SG-RM]
3. The SG-RM to work towards finalisation of proposed draft regulatory materials by mid-2015. [SG-RM]
4. The SG-RM to provide draft regulatory material to ET-ABO and CIMO/TT-AO by July 2015. [Chair ET-ABO, Secretariat]
5. The SG-RM to submit the regulatory materials to ET-ABO Session 1 for discussion and approval. [2nd half 2015, Chair ET-ABO]
6. ET-ABO to submit regulatory material to ICT-IOS. [2016, Chair ET-ABO]

It was agreed that the Secretariat would coordinate the drafting and finalization of the final report of the Meeting with a view to publishing the report by mid-January 2015.

7 CLOSURE OF THE SESSION

The meeting session was closed at around 3pm on 5 December 2014.

ANNEX I

LIST OF PARTICIPANTS

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ANNEX II

Draft regulations for eventual inclusion in Section 2.5 of the Manual on the GOS

2.5 Aircraft Meteorological Stations

1. AIRCRAFT-BASED OBSERVATIONS

1.1 Introduction

1.2 Requirements

2.5.4 Aircraft reports shall, at a minimum, satisfy the requirements of International Air Navigation (for details see the Technical Regulations (WMO-No. 49), Volume II — Meteorological Service for International Air Navigation, Part 1, [C.3.1.1 5).

Members shall obtain and maintain requirements for ABO.

Member shall endeavour to obtain ABO to meet requirements for upper air data in support of the WWW Programme and Applications Areas.

1.3 Sources of Aircraft-based Observations

1.4 Quality Management

1.5 Provision of Aircraft-based Observations on the GTS

1.6 Data Management and Reporting

1.7 International and Regional Planning and Capacity Development

2. AIRCRAFT-BASED OBSERVING SYSTEMS

2.1. AMDAR

2.1.1 Requirements and Planning

2.1.2 Design and Implementation of the AMDAR system

2.1.3 Operations

Members shall ensure that a permanent digital record of all reported aircraft-based observations and associated metadata is maintained.

Members should ensure that sufficiently higher resolution measurements or observations, i.e. generally level 2 data, are archived so that reported observations can be retrieved, recreated or reconstructed.

Note: More information on data processing and data levels is provided in the Guide to the GOS, Part V, Reduction of Level I Data.

Observation reports shall be reported with reference to UTC time.

Observation reports shall have a time stamp indicating the time of measurement with a minimum temporal resolution of 1 second with respect to UTC.

Comment [1]: Need a general regulation on provision of ABO - e.g. adaptation of MoG, 2.5.1.

Comment [2]: Statements of where ABO are derived from:
AMDAR
ICAO
Other

- Reference to the guide for description etc.

Comment [3]: From MoG

Comment [4]: Members shall endeavour to obtain ABO from the following sources as a minimum:
AMDAR (Shall)
ICAO (Shall)
Other (Should)

Comment [5]: ABO shall be QC'd in accordance with the GtG.

Members shall monitor the quality of their ABO data.
Note: see the GtG.

Members shall operate their ABO observing systems in accordance with MoW QM.

Comment [6]: Members shall ensure that data provided on the the GTS meets requirements for Res 40.

Members shall use BUFR to submit data on the GTS.

Members shall submit the following met. variables as a minimum...etc.

Comment [7]: Members should maintain historical observational metadata for aircraft-based observational data, systems and operational aircraft.

Note: Requirements for reporting observational metadata according to the WIGOS Metadata Standard are provided in the Manual on WIGOS ...

Comment [8]: WMO Members should provide support for the continued development of the ABOP through the following actions:

- Contribute financial support to the ...

Comment [9]: Members shall endeavour to develop AMDAR programmes so as to meet requirements for upper air data according to the RRR.

Comment [10]: The AMDAR observing system of Members shall endeavour to meet the following reporting requirements as a minimum:

- Vert. res. of 10 hPa in the lower ...

Comment [11]: Members shall ensure that a permanent digital record of all
reported aircraft-based observations and associated metadata is maintained. ...

Members shall develop, implement and document policy and procedures for routine maintenance of the ABO system that will ensure requirements and standards for operational performance are maintained.

Plans and procedures for routine maintenance should include provisions for maintenance of all ABO system components and sensors, related infrastructure and materials.

A centralised system for monitoring ABO network status and health and data products should be utilised and integrated as a component of the maintenance regime.

Maintenance documentation should be made available to relevant users and stakeholders.

Maintenance operations, their duration and interruptions to data or services should be recorded within the metadata record.

Members should flag or remove as necessary observational data that is impacted by maintenance activities.

The maintenance regime should be planned and adjusted as necessary to accommodate known or expected environmental, weather and climate factors.

Members shall ensure that their AMDAR system is operated in accordance with the following general requirements:

- Put in place agreements with partner airlines to ensure that airlines take responsibility for those responsibilitiies identified in [REF section 2.1.3.1.2 below] and aircraft-based observations are able to be made available to all WMO Members on the WMO Global Telecommunications system in accordance with the requirements of WMO Resolution 40.
- In consultation with airline partners, configuration of AMDAR onboard software (AOS) in accordance with requirements for upper air data and aircraft-based observations (see [REF section 1.5])
- If utilised as part of the AMDAR programme infrastructure, ensure configuration and operation of ground-based optimisation systems in consultation with airline partners.
- Processing of AMDAR messages and observational data received from partner airlines - see [REF section 2.1.3.3].
- Operation of their AMDAR observing system in accordance with requirements for WIGOS Quality Management - See [REF sections 1.7 and 2.1.3.3]
- Quality control of AMDAR observations - see [REF section 2.1.3.3].
- Reporting of aircraft-based observations observational and metadata in accordance with national, regional and international requirements and for provision of such data on the WMO Global Telecommunications System - see [REF sections 1.8, 2.1.3.4 and 2.1.3.5].
- Monitoring of operational systems and observational data (see [REF sections 1.7 and 2.1.3.3]
- Management of incidents, including the identification and rectification of faults - see [REF 2.1.3.6].
- Maintenance of the observing system components - see [REF 2.1.3.8]
- Planning, implementation and documentation of changes in the operational practices and procedures of the observing system - see [REF 2.1.3.7]

WMO Members shall develop and implement policy and procedures for quality monitoring and quality assessment of AMDAR observations made by their AMDAR programme.

Members shall use the monitoring information and reports provided by the WMO Lead Center for Aircraft Data as an integrated component of the quality management operations of their AMDAR programme.

Members shall develop procedures for the analysis of available monitoring information and take prompt and appropriate corrective action (see [REF 2.1.3.6]) for systemic faults and issues identified that adversely affect the quality of aircraft-based observations transmitted on the WMO GTS.

Members should ensure that they develop and implement policy, plans and procedures for each of the AMDAR component systems so as to ensure that their operation is maintained and ensured at the highest possible level of availability and in order to meet both national and international requirements for the continuous and uninterrupted provision of AMDAR data products.

2.1.4 Capacity Development

Comment [12]: Members should ensure that staff are adequately trained for competency in the following areas of operational practices relating to aircraft-based observations and operation of AMDAR programmes

2.2 ICAO ABO Systems
2.3 Other ABO Systems

END REGULATIONS

ANNEX III

Draft regulations for eventual inclusion in Section 3.4 of the Guide to the GOS

New Draft for Guide to GOS, WMO-No. 488, 3.4 Aircraft Meteorological Stations.

DRAFT HISTORY

Version	Author	Changes Made	Date
V1D1	ET-ABO Sub-group on Regulatory Material	Draft 1 of Version 1 – Version produced at the conclusion of meeting of SG-RM.	19 Dec 2014

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1. AIRCRAFT-BASED OBSERVATIONS

1.1 Introduction

In the context of this guide, aircraft-based observations (ABO) are defined as a set of measurements of one or more meteorological variables, along with the required measurement metadata, made at a particular time or according to a defined schedule at a location or series of locations in three dimensional space from an aircraft platform. Such observations might be made or obtained from commercial passenger, military, private business, unmanned or other aircraft, utilising either existing or purpose-deployed sensors and systems.

Ideally and whenever possible, ABO should be made so as to best meet or contribute to the meeting of meteorological requirements for upper air data as defined in section 1.5.1.

The thousands of aircraft flying through the atmosphere every day offer an efficient and cost effective way to gather meteorological information. While flying, the aircraft's sensors measure air temperature, wind speed and direction and other variables of the atmosphere as this information is necessary for the aircraft's navigation systems and operations performance monitoring. Part of this information usually remains onboard in the aircraft's computers while other parts are transmitted to the airline for semi on-line aircraft performance monitoring by its technical division. The meteorologically relevant information can be accessed by a specific software package for the production of upper air information otherwise not available because of the lack of other upper air observation systems.

In some cases where no sensor data or an appropriate communication system is or can be made available, the installation of equipment from other commercial operators, including additional sensors, may be used for the same purpose.

Collaboration and cooperation between the meteorological societies and airlines and the aviation industry on the provision of this kind of upper air information will result in unique benefits to the meteorological services and to the aviation industry.

1.2 History and Background

The history of the use of an aircraft platform as a meteorological observing system goes back to the late 1910's when so called meteographs were mounted to one of the wings of early military biplane aircraft. A meteograph made recordings of air pressure, air temperature and humidity. The data were used for tracking layers of air in the higher atmosphere. Once or twice per day pilots flew pre-defined tracks for 1 hour up to 5000 to 6000 meters.

Aircraft soundings were discontinued in the early 1940s with the advent of the radiosondes.

The use of modern navigation and communication systems in the 1960s and 1970s sparked renewed interest in the use of aircraft to measure and report meteorological data. Automated Weather Observations by aircraft was first used to relay wind and temperature data in support of the Global Weather Experiment FGGE[1][1] in 1978-1979. One of the instruments contributing to the FGGE dataset was a newly developed automated weather observing system installed in aircraft, called (prototype) ASDAR (Aircraft-to-Satellite DAta Relay) providing wind and temperature information from different levels of the atmosphere. The information was transmitted through the Geostationary Meteorological Satellite System for insertion onto the WMO Global Telecommunication System (GTS).

A consortium of 10 WMO Members funded the industrial development of the next generation ASDAR equipment which was operational in the period 1991-2007. The development was supervised by the Consortium for ASDAR Development (CAD). For support of the operational phase the CAD was transformed into the Operational Consortium for ASDAR Participants (OCAP).

[1] First GARP (Global Atmospheric Research Program) Global Experiment (FGGE)

The OCAP managed a Trust Fund for the financial support of the ASDAR operations and expansion, and for contracting a Technical Coordinator.

The advent of flight computers in modern aircraft allowed an alternative approach to ASDAR by tapping the data from innate systems and instruments on the aircraft. In addition to alleviating the requirement to fit aircraft with expensive, purpose-built hardware, this approach made it possible to retrieve valuable atmospheric information and transmit it in (near) real-time using the aircraft communications system through the installation of a dedicated software package only. This new approach was named AMDAR (Aircraft Meteorological DAta Relay) and is now an operational component system of the WMO Global Observing System (GOS). Its description and requirements for operation are provided below in section 2.1.

1.3 Description of Aircraft-based Observations Guidance

Observations are to be made by aircraft operating on international air routes. This is regulated by WMO and the International Civil Aviation Authority (ICAO) and described in WMO-No. 49, Technical Regulations, Volume 1 and 2. For the purpose of this Guide a distinction is made between three categories of ABO:

1. **WMO Aircraft-based Observations**
2. **ICAO Aircraft-based Observations**
3. **Other Aircraft-based Observations**

1.3.1. WMO Aircraft-based Observations

Meteorological observations from commercial aircraft operating on national (and international) routes and based on agreements negotiated between NMHSs and partner airlines. These observations are managed according to WMO Regulations in line with WMO No. 49, Volume 1, including the Annexes (*e.g.* Manual on the GOS, Part III, par. 2.5 Aircraft meteorological stations)

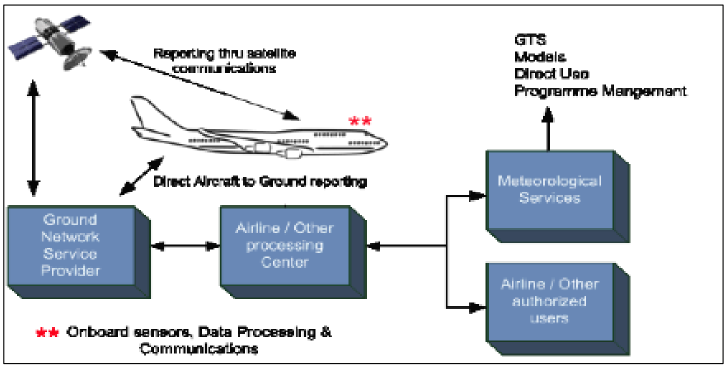
The major part of this Guide describes aircraft-based observations according to category **2. (WMO Aircraft-based Observations)**: what they offer to meteorology, how they can be planned, organised, operated and the data managed and made available to WMO Members and to research.

The WMO AMDAR (Aircraft Meteorological DAta Relay) observation system cooperates with airlines, through national meteorological services, and collects the following meteorological data from commercial aircraft and distributes the data to the meteorological services:

- High resolution [2]vertical profiles of air temperature, wind speed and direction;
- Regular real-time reports (e.g. every 5-10 minutes) of meteorological variables while the aircraft is en-route at cruise level;
- Accurate measurement of coordinates (time, latitude, longitude and pressure altitude);
- Measurement of turbulence as DEVG (Derived Equivalent Vertical Gust) and/or, EDR (Eddy Dissipation Rate), and
- Water vapour or humidity (from suitably equipped aircraft).

The illustration below gives a simplified overview of the system. Details will be explained in section 2.1 of this Guide.

[2] Vertical resolution of around 100 metres in the lower troposphere (to 700 hPa) and temporal resolution of up to around 1 profile per hour depending on fleet size and configuration for reporting and AMDAR fleet traffic at individual airports



1.3.2. ICAO Aircraft-based Observations

ICAO aircraft-based observations are regulated by WMO-No. 49 Technical Regulations, Volume 2, Meteorological Service for International Air Navigation (Chapter 5, AIRCRAFT OBSERVATIONS AND REPORTS), also published by the International Civil Aviation Authority (ICAO) and described in their publication Annex 3 to the Convention on International Civil Aviation. It is stated that Each Contracting State to the Convention on International civil Aviation shall arrange for observations to be made by aircraft of its registry operating on international air routes and for the recording and reporting of these observations. The following aircraft observations shall be made:

a) routine aircraft observations during en-route and climb-out phases of the flight; and

b) special and other non-routine aircraft observations during any phase of the flight.

Although these obligations are clear, it is stated however that aircraft not equipped with air-ground data link shall be exempted from making routine aircraft observations.

For routine aircraft observations it is recommended that when air-ground data link is used and automatic dependent surveillance (ADS) or secondary surveillance radar (SSR) Mode S is being applied, automated routine observations should be made every 15 minutes during the en-route phase and every 30 seconds during the climb-out phase for the first 10 minutes of the flight.

For routine aircraft observations in the case of air routes with high-density air traffic (e.g. organized tracks), an aircraft from among the aircraft operating at each flight level shall be designated, at approximately hourly intervals, to make routine observations. The designation procedures shall be subject to regional air navigation agreement. In the case of the requirement to report during the climb-out phase (ascent), an aircraft shall be designated, at approximately hourly intervals, at each aerodrome to make routine observations.

Apart from routine observations requirements are formulated for special aircraft observations and other non-routine aircraft observations. Examples of special observations are reports of moderate or severe turbulence and moderate or severe icing.

Aircraft observations shall be reported by air-ground data link. Where air-ground data link is not available or appropriate, special and other non-routine aircraft observations during flight shall be reported by voice communications. Aircraft observations shall be reported during flight at the time the observation is made or as soon thereafter as is practicable. These aircraft observations shall be reported as air-reports (indicated as AIREP). Pilot (special and non-routine) reports are indicated as PIREP. Both AIREP and PIREP are disseminated as ‘upper air’ (UA) reports.

For the relay of air-reports the meteorological authority concerned shall make arrangements with the appropriate Air Traffic Services (ATS) authority to ensure that, on receipt by the air traffic services units of:

a) special air-reports by voice communications, the air traffic services units relay them without delay to their associated meteorological watch office (MWO); and

b) routine and special air-reports by data link communications, the air traffic services units relay them without delay to their associated meteorological watch office (MWO) and World Area Forecast Centres (WAFC).

The ABOs produced according to these regulations include PIREP (Pilot Reports), AIREP (Air Reports) reports transmitted over air-ground data links like automatic dependent surveillance (ADS) or secondary surveillance radar (SSR) Mode S. More details can be found further on in Chapter 2 of this Guide.

As stated, it is an obligation of each Contracting State of ICAO to arrange PIREP AND AIREP observations. These observations generally lead to an accumulation of data at reporting points fixed at intervals of 10^{o} longitude or latitude along major air routes, with most altitudes being between the upper standard pressure levels, 300 hPa and 150 hPa. The various ICAO observation systems themselves are only briefly described in this Guide as general information.

Note: *The aircraft-based observations according to the ICAO requirements and regulations are not considered in full detail in this Guide. The reader is referred to the publication WMO-No. 49, Technical Regulations, Volume 2, Meteorological Service for International Air Navigation (or ICAO Annex 3), and the specific documents referenced to in that document.. However, the sections 3.4xx – 3.4yy below serve as additional background information to WMO-No. 49, Volume 2.*

1.3.3. Other Aircraft-based Observations

There are also observations arranged by other commercial operators. These currently include:

- Tropospheric Airborne Meteorological Data Reporting (TAMDAR) sensor by Panasonic Avionics Corporation, a device designed to collect weather data during the flight of an aircraft. The data will be transmitted over Panasonic’s global Ku-band aeronautical network and via the Iridium satellite network in real time, and
- Automatic Flight Information and Reporting System (AFIRS) by FLYHT Aerospace Solutions Ltd. AFIRS uses the Iridium global satellite network to gather, store, and transmit data, regardless of the aircraft’s geographic location.

Both systems provide downlink communication, real-time voice communications, text messaging, and flight following features.

These systems are briefly described further on sections 1.6.3 and 2.3.3 in this Guide.

1.4 Benefits of Aircraft-based Observations

The great benefit of aircraft-based observations and AMDAR data in particular to meteorology, is the fact that the data are derived according to specific meteorological requirements, so that the meteorological parameters measured are reported at a high frequency during the take-off and landings of participating aircraft. What this means is that the aircraft provides a "meteorological snapshot" of the atmosphere on a vertical trajectory, in a very similar way to which balloons bearing meteorological radiosondes do. This generation of vertical profiles by AMDAR aircraft certainly makes the programme useful; but there are three elements of the AMDAR observing system which make it especially valuable:

- AMDAR wind and temperature data have been shown to be similar in data quality (i.e. accuracy or uncertainty of measurement) to that of radiosondes;
- The measurement sensors and systems on the aircraft are able to produce this accurate data at a very high rate or frequency of measurement, thus providing very fine detail within the vertical profiles; and
- Owing to the frequency at which aircraft are landing and taking off from airports, these vertical profiles can be produced on at least a 3-hourly basis at many airport locations.

In addition the aircraft provide data at selected time intervals during flight at cruise level at around 10,000 metres.

It is these features of the AMDAR observing system that have led forecasting meteorologists to provide testimony that these data are very valuable and useful and provide significant improvement to applications for monitoring and prediction of weather systems and phenomena such as:

- Surface and upper air forecasts of wind and temperature;
- Thunderstorm genesis, location and severity;
- Wind shear location and intensity;
- Low cloud formation, location and duration;
- Fog formation, location and duration;
- Turbulence location and intensity;
- Jetstream location and intensity;
- Precipitation amounts and rates; and,
- Conditions leading to aircraft icing.

Meteorologists are able to use modern numerical weather prediction (NWP) systems to precisely quantify the benefits of aircraft-based observations and have determined that these observations are second only to high-volume satellite data in impact on NWP systems. Quantitatively, AMDAR and other aircraft-based observations generally provide an improvement in forecasting ability through a reduction in NWP forecast error of up to 15-20%.

A study[3] in 2014 provided information on the cost-effectiveness of the AMDAR observations relative to all other data sources used in the global NWP systems. When cost estimates for each observing system were included the authors concluded that AMDAR observations have the largest impact per unit cost.

For more detailed information on the benefits and impact of AMDAR data see WMO WIGOS Technical Report 2014-2, The Benefits of AMDAR to Meteorology and Aviation.

1.5 Requirements

1.5.1 Requirements for Upper Air Data

WMO maintains an official repository of requirements for observation of physical variables in support of WMO Programmes and Co-sponsored Programmes. The database is available at http://www.wmo-sat.info/oscar/observingrequirements. These requirements are maintained by the focal points designated for the set of application areas listed in the table below.

No	Application Area	No	Application Area
1	Global NWP	7	Ocean Applications
2	High Resolution NWP	8	Agricultural Meteorology
3	Nowcasting & Very Short-Range Forecasting (VSRF)	9	Hydrology (Hydrological information only; water quality monitoring and information is currently excluded)
4	Seasonal to Inter-annual	10	Climate Monitoring

[3] Eyre, J. and R. Reid, 2014: Cost-benefit studies of observing systems. Forecasting Research Technical Report No: 593. Met Office, Exeter, UK, 11pp.

Comment [13]: The RRR is described in the Manual on WIGOS. A short description of it can be made here but the reader should be referred to the MoW for detail. Wherever possible referencing regulatory material over links should be preferred. URL references should be minimised - better to copy the text.

Comment [14]: It seems the MoW is not published (not available in the WMO on-line library). We can make a referencoe to the Draft MoW from 2014-02-06. However, the only link I found downloads the draft: it seems not to be available for on-line reading.

Concerning you general comment on links contra copy text: Im am not sure to what extent the current draft meets your requirements.

	Forecasts		
5	Aeronautical Meteorology	11	Climate Applications
6	Atmospheric Chemistry	12	Space Weather

The requirements database is the foundation of the Rolling Requirements Review (RRR) process (http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html). The RRR describes data requirements, which are expressed in terms of space/time resolution, uncertainty, timeliness, etc., for each of the required observed variables, and are measures independent of observing technology.

The application areas of most relevance for AMDAR are Global NWP, High Resolution NWP and Aeronautical Meteorology. The requirements are defined for the variables atmospheric pressure, air temperature, wind (horizontal) and specific humidity. AMDAR data are useful also for most of the other application areas.

A description of the background for the requirements can be found in Statement of Guidance (SoG) documents available for each Application Area at http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html#SOG

1.5.2 Requirements for Aircraft-based Observations

Members should ensure that they comply with the following general requirements in relation to the attainment and provision of aircraft-based observations on the GTS and the operation of aircraft-based observing systems:

- Observations should meet the requirements for upper air observational data as defined in section [REF 1.5.1 above].
- Agreements should be made with operators of other ABO systems and data owners and originators to ensure that data can be transmitted on the WMO GTS in accordance with WMO Resolution 40.
- Observational data quality should be managed in accordance with [REF section 1.7 below].
- Observational data should be transmitted on the GTS in accordance with [REF section 1.8 below].
- AMDAR observing systems should be operated in accordance with [REF section 2.1 below].

1.6 Sources of Aircraft-based Observations

Sources of aircraft based observations can be categorized in measurements by or derived from on board sensors installed for the primary functions and from sensors additionally installed for atmospheric observations. The same categorization will hold for the data prosessing and data communication. An overview of these specific categories is shown in the table below:

System / Type	**Auto / Manual**	**Sensors**	**Category**	**Comms**	**GTS**
AIREP	Manual	Pilot (from cockpit display and subjective)	ICAO	ACARS	BUFR/FM41*****

Comment [15]: Need a note here regarding current use of AIREP for ADS and the need to transition to BUFR.

PIREP	Manual	Pilot (from cockpit display and subjective)	ICAO	ACARS	BUFR/FM41*****
ADS-B	Auto	Innate to aircraft	ICAO	ACARS	BUFR*****
ADS-C	Auto	Innate to aircraft	ICAO	ACARS	BUFR*****
Mode S	Auto	Innate to aircraft	ICAO	SRR	BUFR*
AMDAR	Auto	Innate to aircraft	WMO	ACARS	BUFR/FM42
TAMDAR	Auto	Additional	External	Satellite	BUFR
AFIRS	Auto	Innate to aircraft and/or additional	External	Satellite	BUFR

* single level upper air observations only (*i.e.* no profiles)

1.6.1 AMDAR Aircraft-based Observations

The largest source of aircraft-based observations available to WMO Members on the WMO Global Telecommunications System is provided by the Aircraft Meteorological DAta Relay (AMDAR) observing system. A detailed description of the Global AMDAR programme and the regulations and requirements for its operation are provided in section 2.1.

The global AMDAR programme was initiated by the World Meteorological Organization (WMO) and its Members. National or regional AMDAR programmes are operated by WMO Member NMHSs in cooperation and collaboration with their national commercial airlines.

The AMDAR programme is an integrated component of the WMO Global Observing System and the WMO Integrated Global Observing System, which is defined and maintained under the Global Observing System of the World Weather Watch [REF to Manual on the WIGOS, Chapter 7].

1.6.2 ICAO Aircraft-based Observations

Requirements in terms of (mandatory) standards and recommended practices are stated in WMO-No. 49, Vol. 2/ICAO Annex 3, Appendix 4, "Technical Specifications Related to Aircraft Observations and Reports". Distinction is made between routine and special air-reports with air-ground data link and special air-reports by voice communications. Moreover, criteria for reporting the specified variables are stated in this appendix as well. Reference is made to a set of ICAO documents providing details on data processing and delivery. The most relevant documents are:

- Doc 4444 PANS/ATM, Air Traffic Management, (see paragraph 4.12 REPORTING OF OPERATIONAL AND METEOROLOGICAL INFORMATION)

- Doc 8896, Manual of Aeronautical Meteorological Practice (see Chapter 7, AIRCRAFT OBSERVATIONS AND REPORTS)

Comment [16]: Requires definition - surveillance radar? Comms is VHF.

Comment [17]: My understanding is that the AMDAR V7 accommodates both profiles and single level observations.

Comment [18]: When the missing text has been added to 1.6.2 the numbering has to be checked for consistency!

- Doc 9377, Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services (see 4.2 REPORTS OF AIRCRAFT OBSERVATIONS RECEIVED IN ATS UNITS)

note: *Details on the delivery of observational data to the WMO GTS is explained in more detail in paragraph 2.2 (ICAO ABO Systems)*

1.6.2.1 CONTENTS OF AIR-REPORTS

1.6.2.1.1 Routine air-reports by air-ground data link

Comment [19]: From Annex 3 App IV

When air-ground data link is used and automatic dependent surveillance (ADS) or SSR Mode S is being applied, the elements contained in routine air-reports shall be:

- Message type designator
- Aircraft identification
- Data block 1
- Latitude
- Longitude
- Level
- Time
- Data block 2
- Wind direction
- Wind speed
- Wind quality flag
- Air temperature
- Turbulence (if available)
- Humidity (if available)

Note.— *When ADS or SSR Mode S is being applied, the requirements of routine air-reports may be met by the*

combination of the basic ADS/SSR Mode S data block (data block 1) and the meteorological information data block (data block 2), available from ADS or SSR Mode S reports. The ADS message format is specified in the PANS-ATM (Doc 4444), 4.11.4 and Chapter 13 and the SSR Mode S message format is specified in Annex 10, Volume III, Part I — Digital Data Communication Systems, Chapter 5.

When air-ground data link is used while ADS and SSR Mode S are not being applied, the elements contained in routine reports shall be:

Comment [20]: From PANS 4444

Comment [21]: Should yours and Jitze's verious references be added in the text? If so they seem to be incomplete.

Message type designator

Section 1 (Position information)

EnAircraft identification

Position or latitude and longitude

Time

Flight level or altitude

Next position and time over

suing significant point

Section 2 (Operational information)

Estimated time of arrival

Endurance

Section 3 (Meteorological information)

Air temperature

Wind direction

Wind speed

Turbulence

Aircraft icing

Humidity (if available)

Note.— *When air-ground data link is used while ADS and SSR Mode S are not being applied, the requirements of routine air-reports may be met by the controller-pilot data link communication (CPDLC) application entitled "Position report". The details of this data link application are specified in the Manual of Air Traffic Services Data Link Applications (Doc 9694) and in Annex 10, Volume III, Part I.*

Table 7-3. Meteorological content of routine air-reports transmitted via air-ground data link
(All the reports include information on the position of the aircraft in four dimensions.)

ADS and SSR Mode S not being applied	*ADS or SSR Mode S being applied*
Air temperature Wind direction Wind speed Turbulence Aircraft icing Humidity (if available)	Wind direction Wind speed Wind quality flag Air temperature Turbulence (if available) Humidity (if available)

Comment [22]: source: Doc 8896 AN/893

1.6.2.2. CRITERIA FOR REPORTING

When air-ground data link is used, the wind direction, wind speed, wind quality flag, air temperature, turbulence and humidity included in air-reports shall be reported in accordance with the following criteria.

- Wind direction: The wind direction shall be reported in terms of degrees true, rounded to the nearest whole degree.
- Wind speed: The wind speed shall be reported in metres per second or knots, rounded to the nearest 1 m/s (1 knot). The units of measurement used for the wind speed shall be indicated.
- Wind quality flag: The wind quality flag shall be reported as 0 when the roll angle is less than 5 degrees and as 1 when the roll angle is 5 degrees or more.
- Air temperature: The air temperature shall be reported to the nearest tenth of a degree Celsius.
- Turbulence: The turbulence shall be reported in terms of the cube root of the eddy dissipation rate (EDR). For further details, see Annex 3, App. 4, par. 2.6.
- Humidity: The humidity shall be reported as the relative humidity, rounded to the nearest whole per cent.

Note.— *The ranges and resolutions for the meteorological elements included in air-reports are shown in Table A4-3.*

Table A4-3. Ranges and resolutions for the meteorological elements included in air-reports

Element as specified in Chapter 5		*Range*	*Resolution*
Wind direction:	°true	000 – 360	1
Wind speed:	MPS KT	00 – 125 00 – 250	1 1
Wind quality flag:	(index)*	0 – 1	1
Air temperature:	°C	–80 – +60	0.1
Turbulence: routine air-report:	$m^{2/3} s^{-1}$ (time of occurrence)*	0 – 2 0 – 15	0.01 1
Turbulence: special air-report:	$m^{2/3} s^{-1}$	0 – 2	0.01
Humidity:	%	0 – 100	1

* Non-dimensional

Comment [23]: source: Annex 3, App 4

1.6.2. 3 Reporting

Details on reporting aircraft based observations are in **Doc 8896 AN/893 Manual of Aeronautical Meteorological Practice, chapter 7:**

[7.2] REPORTING OF AIRCRAFT OBSERVATIONS DURING FLIGHT

Comment [24]: From 8896

[7.2.1] Aircraft observations are to be reported using the following means:

a) air-ground data link. This is the preferred mode of reporting, applicable both for routine and special and other non-routine aircraft observations; and

b) voice communication. This is to be used only if the air-ground data link is not available or appropriate and is applicable only for special and other non-routine aircraft observations.

[7.2.2] Aircraft observations are to be reported during flight at the time the observation is made or as soon thereafter as is practicable.

[7.3] ROUTINE AIRCRAFT OBSERVATIONS

[7.3.1] Frequency of reporting

When air-ground data link is used and automatic dependent surveillance (ADS) or secondary surveillance radar (SSR) Mode S is being applied, automatic routine observations are made every 15 minutes during the en-route phase and every 30 seconds during the climb-out phase for the first 10 minutes of the flight. When only voice communications are available, no routine meteorological observations by aircraft are made. For helicopter operations to and fromaerodromes on offshore structures, routine observations are to be made from helicopters at points and times as agreed between the meteorological authorities and the helicopter operators concerned.

[7.3.2] Exemptions from reporting

As indicated in 7.3.1, an aircraft not equipped with air-ground data link is exempted from making routine observations, i.e. when voice communications are used, no routine aircraft observations are required.

Note.— *When air-ground data link is used, no exemptions are to be applied.*

[7.3.3] Designation procedures

In the case of air routes with high-density air traffic (e.g. organized tracks), an aircraft from among the aircraft operating at each flight level shall be designated, at approximately hourly intervals, to make routine observations in accordance with the frequency specified in7.3.1. These designation procedures for the en-route phase of the flight are prescribed by RAN agreement and only applicable when air-ground data link issued. In the case of the requirement to report during the climb-out phase, an aircraft is to be designated, at approximately hourly intervals, at each aerodrome to make routine observations in accordance with 7.3.1. The details concerning the required frequency to make routine aircraft observations and the associated designation procedures are shown in Table 7-1.

Note.— *Details on designation procedures for the en-route phase of the flightare contained in theRegional Supplementary Procedures (Doc 7030), Chapter 12— Meteorology.*

Table 7-1. Frequency and associated designation procedures of routine air-reports through air-ground data link

	En-route phase		*Climb-out phase (terminal area)*
	Low-density traffic	*High-density traffic*	
	All aircraft	*Designated aircraft*	*Designated aircraft*
Frequency	One every 15 min		One every 30 s for the first 10 min of the flight
Designation procedures	None	An aircraft at hourly intervals*	An aircraft at hourly intervals at each international aerodrome
*Subject to RAN agreement included in the *Regional Supplementary Procedures* (Doc 7300), Chapter 12 — *Meteorology*.			

1.6.2.1 AIREPS

Data Reception

Provision of data on the GTS

Metadata

Monitoring and Quality Assessment

1.6.2.2 PIREPS

1.6.2.3 ADS-C

1.6.2.4 ADS-B

1.6.2.5 Mode-S

1.6.2.6 Aircraft Observations

The International Civil Aviation Organization (ICAO) maintains the following systems:

- PIREP is a pilot report about actual weather conditions encountered by an aircraft during flight. The PIREP contains information about the weather situation as well as aircraft location, time, flight level and aircraft type. The PIREP is sent usually by radio to nearest ground station where it is encoded and distributed to weather services and air traffic services.
- AIREP, aircraft report or air report, is an automated position report that also can contain weather information observed manually.
- ADS stands for Automatic Dependent Surveillance. Of interest for meteorology are ADS-B (Broadcast) and ADS-C (Contract). In ADS-B the aircraft determines its position via satellite navigation and broadcasts it and can thus be tracked by air traffic control and also by other aircraft. It is possible to derive from ADS-B wind information of same quality to AMDAR but the quality of derived temperature information is so far not satisfactory. In ADS-C temperature and wind data are generated by the same onboard sensors as those used to generate AMDAR reports. The reports are received by the Air Traffic Services who forward the meteorological information to the World Area Forecast Centres (WAFCs).

1.6.3 Other Aircraft-based Observations

1.6.3.1 TAMDAR

Panasonic Avionics Corporation maintains a system called TAMDAR (Tropospheric Airborne Meteorological Data Reporting) that is set up in a different way compared to an AMDAR programme. The company negotiates with an airline and installs new hardware with a multiple of sensors and software on the aircraft. Amongst other functions, the hardware collects the meteorological data, and transmits it via satellite data link to the Panasonic Operations Centre. These data are then sold to the meteorological service providers. Under the current business model, the customers have not been allowed to distribute the TAMDAR data on GTS. In the CIMO Guide No 8 (Part II, Chapter 3) is a more detailed technical description of TAMDAR

Data Reception

The company will negotiate an agreement with the NMHS how and in what form the data will be delivered. The NMHS may have to decode the data into a format that can be handled for data assimilation into NWP and for other operational purposes.

Provision of data on the GTS

If the NMHS, according to the contract, will be allowed to transmit the data on the GTS according to WMO Resolution 40 the NMHS has to code the data in BUFR in the same way as AMDAR data according to regulation in GDPFS (the global Data-processing and forecasting System), see also section 2.1.3.4.

Metadata

It is highly recommended to collect metadata about the observations. If the contract with Panasonic allows the data to be transmitted on the GTS, metadata should be collected and reported in the same way as for AMDAR data, see section 2.1.3.5

Monitoring and Quality Assessment

Monitoring and quality assessment of the TAMDAR data should be carried out by the NMHS as part of its regular quality management system in the same way as for AMDAR data (see section XX)

1.6.3.2 AFIRS

FLYHT Aerospace Solutions Ltd has an avionics system (hardware and software) called AFIRS. This functions as an alternative to the ACARS communication system used by many airlines, but uses Iridium Satellite for data transmission. This allows “ACARS like” functionality in regions not covered by the ACARS VHF network. If AFIRS is installed on aircraft with sensors of sufficient quality, the meteorological data generated can be used in an AMDAR programme.

Data reception

The company will negotiate an agreement with the NMHS how and in what form the data will be delivered. The NMHS may have to decode the data into a format that can be handled for data assimilation into NWP and for other operational purposes.

Provision of data on the GTS

In the contract between the company and the NMHS there should be no limitation to the right to transmit the data on the GTS according to WMO Resolution 40. The NMHS has to code the data in BUFR in the same way as AMDAR data according to regulation in GDPFS, see (REF section 2.1.3.4).

Metadata

Metadata about the observations should be collected and reported in the same way as for AMDAR data, see (REF section 2.1.3.5).

Monitoring and Quality Assessment

Monitoring and quality assessment of the data should be carried out by the NMHS as part of its regular quality management system in the same way as for AMDAR data (see section 2.1.3.3).

1.7 Quality Management

Comment [25]: Jitze to revise with respect to:

WMO QMF
Manual on WIGOS
CIMO Guide Vol 3

1.7.1 WMO Quality Management System

The adoption of a quality management approach to the delivery of products and services of National Meteorological and Hydrological Services (NMHSs) has been driven by a number of imperatives. A key imperative has been the requirements of the International Civil Aviation Organization (ICAO) for the delivery of aviation weather services.

It was recognized that in the field of meteorological service for international air navigation quality management had become increasingly important and there was a need for a properly organized quality system to ensure continued optimum affordable quality of data and products provided by the aeronautical meteorological services.

The World Meteorological Organization first addressed quality management in May 2003, at the Fourteenth World Meteorological Congress. Congress decided that WMO should work towards a Quality Management Framework (QMF) for NMHSs that would include the following elements to be dealt with on a phased basis: (a) WMO technical standards; (b) quality management systems including quality control; and (c) certification procedures. Congress also requested the Executive Council to guide the development of the WMO Quality Management Framework (WMO-QMF, see

WMO Technical Regulations Volume IV and also Manual on the GOS Section 2.6) by providing broad guidelines for NMHSs on how to develop their quality management system.

WMO and ICAO jointly developed and published in 2006 the Guide to the Quality Management System for the Provision of Meteorological Service for International Air Navigation (WMO-No. 1001) to facilitate the design, development and implementation of an ISO 9000-compliant quality management system by the aeronautical meteorological services. WMO-No. 1001 is available for download at the WMO AeM Programme website (http://www.wmo.int/aemp/?q=regulations).

Quality management according to ISO 9000 Standards is based on eight principles:

- Customer-focused organisation
- Leadership
- Involvement of staff
- Process approach
- System approach to management
- Continual improvement
- Factual approach to decision-making
- Mutually beneficial supplier relationships

NMHSs are encouraged to undergo third-party certification of their QMS to achieve compliance with the ISO Standard *ISO 9001:2008, Quality management systems – Requirements.* To assist this WMO has produced a Guide to Implementation of a Quality Management System for National Meteorological and Hydrological Services (WMO-No 1100), available for download at the WMO AeMP website (http://www.wmo.int/aemp/?q=regulations). Further developments of documents are found on on the WMO Quality Management Framework (WMO-QMF) Website (http://www.bom.gov.au/wmo/quality_management.shtml). Wherever possible, the Guide will provide hyperlinks to other resources to ensure, as much as possible, the longevity of the document in terms of its currency and on-going value.

1.7.2 WIGOS Quality Management

The WIGOS Technical Regulations (link) and the Manual on WIGOS (link) establish a Quality Management System (QMS) for WIGOS. The purpose of the WIGOS QMS is to provide a comprehensive system of recommended procedures and practices to direct and control the quality of basic and specialised environmental data derived from WIGOS and to ensure implementation of the WMO Quality Management Framework Quality Policy, as it applies to environmental data derived from WIGOS observing systems.

Through the operation of WIGOS and the WIGOS QMS, WMO is dedicated to ensuring optimum affordable quality for all meteorological, climatological, hydrological, marine and related environmental data and data products.

The WIGOS QMS is established through the specification and documentation of:

1. A Quality Plan and,
2. The WIGOS Quality Manual.

The WIGOS QMS establishes regulations and guidelines on:

- Compliance, Certification and Accreditation
- Roles in the Operation of the WIGOS QMS
- Development and Implementation of Quality Management Systems
- Quality Control Practices
- Quality Assurance Practices
- Quality Monitoring and Quality Improvement Practices
- Management of Incidents and Change

Comment [26]: This is a short version of the text about WIGOS Quality Management on the WMO Web

Comment [27]: When the MoW is published, correct links should be established.

· Maintenance of Documentation

1.7.3 Integration of ABO into Member QMS

Quality Control, QC, is part of AMDAR Data Management (AMDARDM) and applies at all stages of data production and dissemination. The main requirements are dealt with in more detail in Appendix XXX (= use relevant material from ARM Appendix IV).

Real-time QC of AMDAR data is needed

(i) At the measurement stage on board the aircraft.

(ii) At the code conversion stage to GTS format.

(iii) At the data assimilation stage for real-time applications.

The first two stages are necessary to ensure adequate quality of the data released for general user applications. The third stage is desirable to eliminate or flag erroneous data from model or analysed fields or for subsequent climate or archive purposes.

Quality evaluation (QEV) is a process carried out in near or non-real time to apply statistical tests to individual or sets of AMDAR reports. This process will generally identify long-term sensor drift or constant measurement bias as well as highlighting platforms that are consistently transmitting poor quality data. The QEV process is an important link in the total AMDAR Quality system and provides the most important feedback path for remedial action. Guidelines for an AMDAR quality system including QC, QEV and subsequent actions are given in Appendix XXX.

1.7.4 Quality Monitoring and Improvement

1.8 Provision of Aircraft-based Observations on the GTS

1.9 Observational Metadata Requirements and Management

Observational metadata refers to all types of metadata necessary to interpret the observational (sets of) data. Information contained in the metadata database will be related to the specific type of aircraft, the sensors, the siting, maintenance issues and calibration figure. Also metadata on the specific software (or calculus) used to process data to generate the reported variables. Also metadata related to quality control processes, data communication practices, data processing and delivering centres shall be provided and archived. The best practice is to report metadata together with the observational metadata (i.e within the same BUFR bulletin).

Further details related to aircraft based systems can be found in par. 2.1.4

1.10 International and Regional Planning and Capacity Development

1.10.1 WMO Aircraft-based Observations programme

In order to coordinate and promote the development of aircraft-based observations and national (and regional) AMDAR programmes, the WMO Executive Council decided at its forty-ninth session in 1997 to establish a WMO Panel on AMDAR, composed of WMO Members that operated, or intended to operate, national AMDAR programmes. In 1998 the AMDAR Panel took over the responsibilities for the operation of AMDAR, the remaining ASDAR units and the Trust Fund.

At its 16th Session (2003), WMO Congress agreed with a recommendation made by the WMO Commission for Basic Systems (CBS) that AMDAR should become fully integrated into the WMO World Weather Watch (WWW) Programme. In 2007, at its 17th Session, Congress paved the way for the AMDAR observing system to become a recognised, operational component of the WWW Global Observing System.

At its 15th annual Session (2012) the WMO AMDAR Panel agreed that all was in place within WMO and its Technical Commissions to formally hand over full responsibility for the AMDAR

Comment [28]: See section 2.6 of the Manual on WIGOS for some references or words relating to adaptation of Member QMS for observing system management.

Comment [29]: This belongs in section 2.1 QC

Comment [30]: Possibly move material from section 2.1 to here.

Possibly create a super section "Aircraft-based Observations Data Management and Reporting" including the ABO DM diagram.

Comment [31]: Possibly requirement for guidance on:

- latency of buffered observations/reports (e.g. enroute).
- number of observations per BUFR report.
- combining ascent/descent observations into profiles in the BUFR message.
- guidance document on use of various AMDAR BUFR templates and how to encode the various elements (Version 7 AMDAR Template).

Comment [32]: Integrate with section 1.8 as per last comment.

observing system and the AMDAR Trust Fund, and for the Panel to cease its activities. The international Aircraft-based Observations Programme (ABOP), which includes AMDAR, is now supported by an Expert Team on Aircraft-based Observing Systems (ET-ABO) within CBS and also an Expert Team on Aircraft-based Observations (ET-AO) within the Commission for Instruments and Methods of Observation (CIMO).

The tasks and activities of the two Expert Teams include the provision of technical support for development and maintenance of all aircraft-based observing systems and for management of international standards and practices associated with aircraft-based observations.

Fig.ZZ below represents the current governance and programmatic management of aircraft-based observations within WMO.

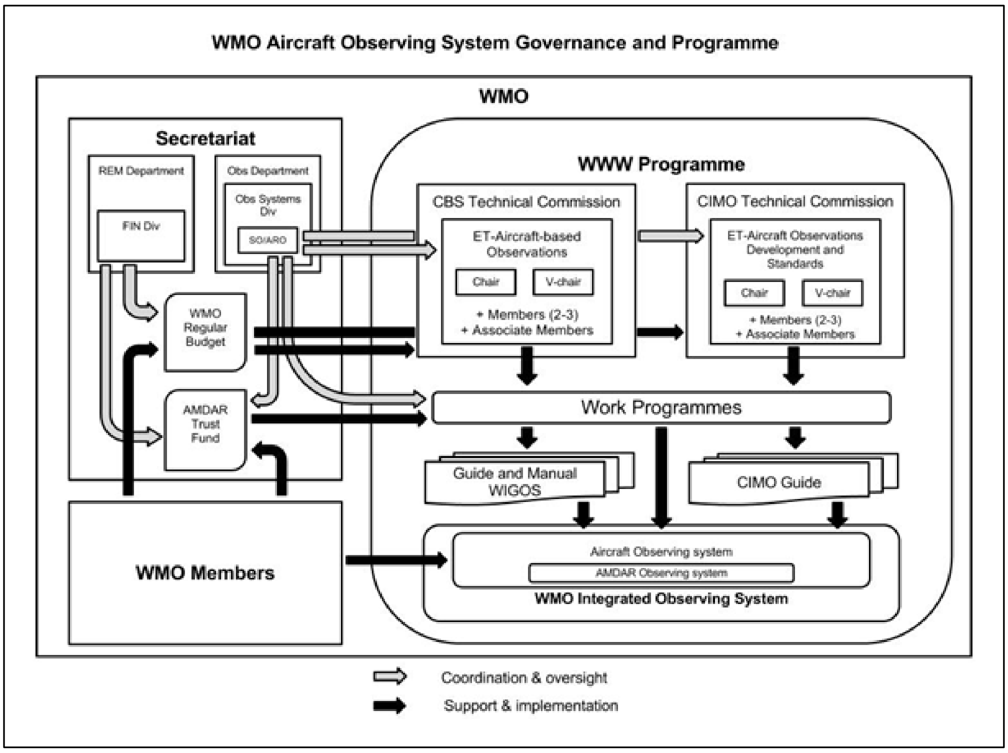


Figure ZZ: Aircraft-based Observing System Governance and Programmatic Structure.

1.10.2 Projects and Development

Under the Aircraft-Based Observations programme (ABOP) defined above in [REF Section 1.10.1], WMO Technical Commissions have instigated a regional approach to aircraft-based observations development in collaboration with WMO Regional Associations (RAs) and their Members. The ABOP intends to assist RAs in developing and maintaining ABOP Regional Implementation Plans (A-RIPs) in each of the six WMO regions. These A-RIPs will be based on and in line with the relevant actions of the CBS Implementation Plan for Evolution of Global Observing Systems (EGOS-IP) [REF].

While AMDAR is now a mature and stable operational observing system, there are many developments and enhancements underway or planned that are expected to greatly improve the system and its operational coverage.

These include:

1. Development of new programmes that will improve global upper-air data coverage over currently data-sparse areas including:

- Regions I and III
- Eastern Europe
- Western Asia
- The Southwest Pacific
- Central America
- The Middle East

2. Implementation of water vapour measurement as a component of the AMDAR Observing System.

3. Implementation of turbulence monitoring and reporting.

4. Implementation of icing monitoring and reporting.

5. Wider implementation of ground-based AMDAR Data Optimisation.

6. Greater integration of AMDAR standards and protocols into the avionics and aircraft manufacturing process.

7. Implementation of routine data targeting in support of weather systems monitoring and prediction.

WMO Members should provide support for the continued development of the ABOP through the following actions:

- Contribute financial support to the AMDAR Trust Fund in line with WMO Congress resolutions.
- Contribute staff resources to the membership of relevant WMO Technical Commission and Regional Association work teams and groups.
- Endeavour to obtain and provide aircraft-based observations on the WMO GTS.
- Endeavour to develop and maintain operational AMDAR observing systems in line with national, regional and global requirements.

1.10.3 Training and Outreach

Comment [33]: Possibly bring material from 2.1 to here.

1.10.3.1 Training Requirements

Members should ensure that staff are adequately trained for competency in the following areas of operational practices relating to aircraft-based observations and operation of AMDAR programmes:

- Interaction and negotiation with aviation representatives and contacts for collaboration on aircraft-based observations and AMDAR programme participation.
- Specification of technical and functional requirements for AMDAR observing system planning and design.
- Information Technology skills supporting data communications and data processing systems infrastructure development and maintenance.
- Scientific and meteorological data analysis.
- Systems and data quality management.

For further information refer to Section 2.1.4 Capacity Development

1.10.3.2 Outreach

It is critical to the maintenance and continued development of the AMDAR observing system that the interests of Members are represented and promoted to the important aviation organisations, associations and forums.

WMO and the Aircraft-Based Observations programme (ABOP) promote aircraft-based observations and the AMDAR observing system through a range of activities which include:

- Maintaining the ABO and AMDAR areas of the WMO website [REF see: http://www.wmo.int/pages/prog/www/GOS/ABO/index_en.html];
- Publishing the AMDAR Newsletter and maintaining the News and Events website [REF see: http://www.wmo.int/amdar-news-and-events/];
- Maintaining statistical reports and quality monitoring information on the WMO website [REF see: http://www.wmo.int/pages/prog/www/GOS/ABO/ABO_Data.html]
- Developing and maintaining guidance on the benefits and business case for aviation and airline collaboration on aircraft-based observations [REF see: http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/resources/index_en.html]

2. AIRCRAFT-BASED OBSERVING SYSTEMS

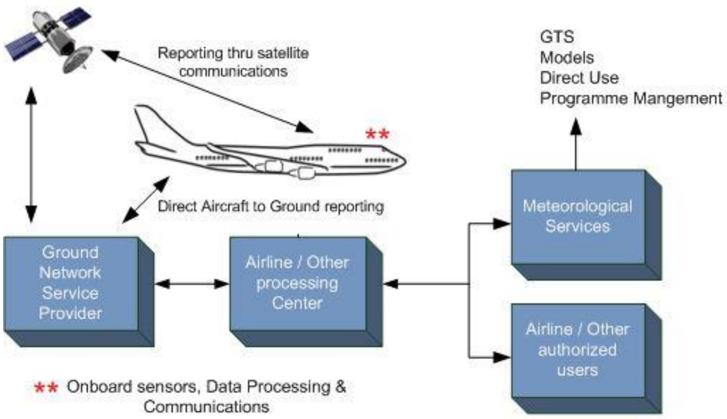
2.1. AMDAR

Comment [34]: Check for repetition in Chapter 1.

Aircraft Meteorological DAta Relay (AMDAR) is a World Meteorological Organization (WMO) meteorological observing system that facilitates the fully automated collection and transmission of weather observations from commercial aircraft. The AMDAR programme is an integrated component of the WMO Global Observing System (GOS) of the World Weather Watch (WWW) Programme (reference http://www.wmo.int/pages/prog/www/index_en.html) The system is operated by WMO Member NMHSs in collaboration and cooperation with partner airlines and has grown rapidly and continuously over the past two decades.

While the AMDAR programme is currently served by a worldwide fleet of over 3000 aircraft contributing more than 600,000 high quality upper air observations per day, there are still many areas of the world with little or no AMDAR coverage and WMO is urging Members to work towards improving upper air coverage of the GOS by developing new and expanding existing national and regional AMDAR programmes.

The figure below provides a general depiction of the AMDAR system in which onboard sensors, computers and communications systems collect, process, format and transmit the data to ground stations via satellite and VHF radio links. The transmission of this data is most often performed by the aircraft's ACARS (Aircraft Communications Reporting and Addressing and Reporting System) system. Once on the ground, the data is then relayed to the global network of national meteorological services and other authorised users.



The primary data set reported from the AMDAR programme includes position in time and three dimensional space, wind speed and direction, and ambient temperature. Additional parameters are optionally reported including, a turbulence metric and humidity, the latter requiring the deployment of a water vapour measurement sensor.

See 2.1.3.2.2 for details on reporting AMDAR data.

2.1.1 Requirements and Planning

The requirements for the operation of an AMDAR programme are provided below in [REF section 2.3.1].

When considering developing or participation in an AMDAR programme the NMHS should be ready and capable to fulfil the following requirements:

- Ensure that requirements for upper air data are met (see section ???).
- Ensure compliance with relevant standards:
  - - AOSFRS
  - - ARINC 620
  - - CIMO Guide
- Compliance with WMO Resolution 40.
- QC of data (see AMDAR QC in section 2.1.3.3).
- Delivery of data with reference to the Manual on Codes (see section 2.1.3.4).

When considering the development and implementation of a national AMDAR programme with one or more partner airlines, it is necessary for NMHS to address each of the following basic topics and requirements:

- Assessment of national, regional and global requirements for upper air data;
- Assessment of national airlines' capabilities and coverage;
- Obtaining airline contacts and commencing negotiations with the airline(s);
- Building a business case for airline participation;
- AMDAR programme cost considerations;
- Contracts and agreements between NMHS and Airlines;
- Design and implementation of the AMDAR system; and
- Data display and use.

Each of these aspects is described in this document but can be considered to provide an overview only of the various considerations for each topic.

2.1.1.1 Assessment of requirements for upper air data

Before commencing the development of an AMDAR programme the requirements of upper air data users and applications areas, including national, regional and global, should be taken into consideration. These requirements should be assessed against the capabilities of the current national composite upper air observing system and the ability of an AMDAR programme to fill gaps and/or to provide an efficiency dividend, for example through a reduction in operational costs based on a possible reorganization of the upper air observing system in conjunction with the AMDAR programme development. Other upper air observing systems that might be considered in such an analysis are radiosondes, radar wind profilers, polar orbiting and geostationary satellites and other ground-based remote-sensing systems.

The national aspects of such an analysis can be undertaken only by each NMHS individually in consideration of both the current configuration of the composite upper air observing system and its likely future evolution.

An obvious consideration is that the AMDAR programme coverage is fully dependent on when and where the participating airlines fly, and that their programmes and flight schedules can vary from

Comment [35]: This section is a summary of the WIGOS Technical report 2014-02 Requirements for the Implementation and Operation of an AMDAR Programme.

day to day, week to week, month to month and seasonally depending on customer demand and other airline-dependent factors.

Given the international operations (i.e. regional and long-haul international flights) of many national airline operators, it is also important to take into consideration that the AMDAR programme, by its nature, offers the opportunity to collaborate with regional and international NMHS partners to share and optimise the efficiency and coverage that can be provided. It is highly recommended that Members work within their respective Regional Associations and other international forums to investigate and take advantage of opportunities to collaborate on a regionally coordinated approach to national AMDAR programme development, including the possibility to share costs associated with infrastructure (e.g. ground-based data processing systems), resources and data production (e.g. an NMHS might pay the costs for data generated within its country by another AMDAR programme).

2.1.1.2 Assessment of national airlines capabilities and coverage

Potential operators of a national or regional AMDAR programme should start with a preliminary assessment of the national airlines' aircraft fleets and analysis of the operational routes serviced by the airlines.

The overall aim of the survey and analysis of the national airlines should be to determine what coverage might be obtained by equipping one or more fleets of aircraft and which combination of airlines and aircraft fleets most efficiently provides the optimal coverage that best meets established requirements for upper air data.

Generally detailed information on the airline's fleets and the flight routes that they operate can be found on the airline's website. If not, then it will be necessary to establish direct contacts within the airline (see section below) and obtain this information from those contacts.

The following aspects and questions regarding the airline especially require consideration:

- Which types of aircraft does the airline operate and over which routes does each aircraft type tend to fly?
- Of these types, which fly domestic routes and which fly internationally?
- What is the age of the aircraft? The more modern the aircraft, the more likely they will be able to accommodate an AMDAR software application. Note however that it will eventually be necessary to determine exactly which avionics the aircraft have and whether or not they will support an AMDAR software application.
- Of prime importance is whether the airline and aircraft have ACARS (communications) capability, which enables the near-real-time automated reporting functionality required for AMDAR programme operation.
- Which airports does each airline and aircraft fleet service routinely?
- Based on the airline flight schedules, how many vertical profiles per day at each airport are likely to be obtained through equipping the different aircraft types?
- Is the airline well established, stable and likely to continue operation well into the future?
- Does the airline have a strong maintenance division within the airline? While this is not crucial and, in fact, there are many airlines that outsource their maintenance operations, it is certainly beneficial to be able to liaise directly with technical people and engineers within the airline that understand the engineering aspect of aircraft maintenance and monitoring via avionics systems.

Once the initial analysis of national airlines above has been undertaken, it is then necessary to make a more firm determination on whether or not the airlines and aircraft have the required technical capabilities. This can be done by asking the airline to complete a questionnaire, the

Airlines AMDAR Compatible Systems Survey that is available from the WMO AMDAR Resources website[4].

The survey could be completed either before or after the airline has agreed to participate in the AMDAR programme and will be necessary to identify the onboard avionics type and capabilities, which will determine the suitability and requirements for AMDAR onboard software (see section X below).

Once the survey has been completed it can be returned to the WMO Secretariat, who can assist in providing further advice regarding AMDAR software development.

For a global summary of airlines operating AMDAR suitable aircraft, highlighting those that have been targeted by WMO to contribute to extending global AMDAR coverage, it is also recommended to consult the WMO report, *AMDAR Coverage & Targeting for Future Airline Recruitment, February 2013*[5]

2.1.1.3 Obtaining airline contacts and commencing negotiations

Once it has been confirmed that one or more national airlines operates aircraft that might contribute to the WMO AMDAR programme and the upper air data requirements, the NMHS should seek to establish some key contacts within the airline so as to be able to begin negotiations and present a business case to the airline for participation in the programme.

Airline Contact	Role in the Airline	Role in AMDAR Programme Development and or Operation	Comment
Airline CEO or other senior executive officer	Executive manager and high level decision maker	· May understand the impact of weather on airline operations. · May be a recipient of the business case for programme participation. · May provide initial, high-level decision on airline involvement in the programme.	· Unlikely to be involved in detailed negotiations. · Unlikely to be involved in ongoing aspects of the programme.
Senior Pilot	Senior representative of pilots to airline executive and is influential in airline decision making, particularly in relation to those aspects of flight operations and safety	· Will understand the impact of weather on airline operations and efficiency, including fuel usage. · May provide influence on high-level decision on airline involvement in the programme	· May be involved in the initial negotiations · Unlikely to be involved in ongoing aspects of the programme.

4 http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/resources/index_en.html

5 Available from: http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/resources/AMDAR_Coverage_Recruitment_Study.html

		· May be a recipient of the business case for programme participation. · May provide a link to flight operations aspects of the programme.	
Flight Operations Manager	Manager of all aspects of aircraft flight operations and is often the contact that liaises with NMHSs for weather services.	· Will understand the impact of weather on airline operations and efficiency, including fuel usage. · May provide a link to aircraft maintenance and engineering areas of the airline.	· May be involved in the initial negotiations and also the ongoing aspects of the programme. · Often is the first airline contact made by the AMDAR programme manager due to the weather services link.
Avionics and Maintenance Engineering	Responsible for airline aircraft and avionics maintenance.	· Will be involved in determining avionics capabilities. · Will be responsible for AMDAR software integration.	· Can be a useful first-up contact but usually defers to other airline managers regarding participation in the programme and its benefit to the airline.

Once a suitable group of airline contacts has been established, the NMHS should start negotiations with the airline management in order to convince them of the benefits of participation in the programme and then to reach agreement on the operation of the programme, including AMDAR fleet size and configuration, AMDAR software development and integration, implementation and ongoing costs and other factors associated with the design of the AMDAR system (see section X).

2.1.1.4 Building a business case for airline participation

Of critical importance in the process of convincing the airline to participate in the AMDAR programme is the development of a business case by the NMHS which should clearly establish the business relationship between the provision of the AMDAR data, resulting in an improvement to weather forecasting skill and services to aviation by the NMHS, which will lead to improved and more efficient flight operations by the airline, reduction in airline costs (e.g. fuel use) and increased airline customer satisfaction.

For more detailed information on the benefits and impact of AMDAR data, which should be used in developing the business case see:

http://www.wmo.int/pages/prog/www/GOS/ABO/data/ABO_Benefits.html

In particular, the WIGOS Technical Report 2014-1, *The Benefits of AMDAR to Meteorology and Aviation*[6] , provides a detailed suite of information on AMDAR data benefits and impact that should be integrated into or referenced as part of the business case made to the airline.

6 Available at: http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/publications/Benefit_of_AMDAR_Data_to_Meteorology_and_Aviation.pdf

Other important considerations for inclusion and explanation in the business case made to the airline are the following:

- It should be emphasised that the AMDAR software module, once installed and operational, will have no impact on the operation of the aircraft. The AMDAR software is tested and certified to ensure seamless and safe integration into the (non-sensitive part of the) avionics, such as ACMS or its equivalent.
- The AMDAR observations, collected and pre-processed by the special AMDAR software, are interleaved in the routine aircraft data flow over the standard aircraft-to-ground ACARS system.
- The airline may argue that the AMDAR data provided to the NMHS improves weather services generally, which benefits all airlines, including the competitors of the participating airline(s). While this is true, it should be emphasised that there are at least two benefits participating airlines have over non-participating airlines:
    - The performance of onboard sensor(s) providing data to the AMDAR software, which are integral to the operation and performance of the aircraft, can be monitored as a result of the provision of AMDAR data to the NMHS. The NMHS can therefore provide a complimentary service to the airline to inform them if and when a sensor is errant or out of calibration; and
    - The airline can promote its participation in the programme, demonstrating its commitment to improved airline operational performance, greater customer satisfaction and reducing its impact on the environment.

2.1.1.5 AMDAR programme cost considerations

The costs for the development and operation of an AMDAR programme are highly dependent on the relationship between the NMHS and the airline and the extent to which the airline perceives or quantifies the benefits based on the business case for AMDAR programme participation.

Generally, AMDAR programmes have been and are established between NMHS and their partner airlines under the understanding and agreement that the mutual benefits dictate that the NMHS should pay no more that the incremental costs only of establishing and operating the programme in cooperation with the airline.

A costing model for comparing the estimated costs associated with operating an AMDAR programme with those of a radiosonde programme was developed and some summary results are available in Annex 5 of WIGOS Technical Report 2014-1, *The Benefits of AMDAR Data to Meteorology and Aviation.*

In summary, the programme costs are largely dependent on the following factors:

- the communications solutions adopted in cooperation with the airline;
- the contractual arrangements between the particular airline and its data service provider (DSP);
- the volume of AMDAR data generated by the fleet;
- the extent to which the airline perceives and quantifies the benefits of participating in the programme; and,
- the extent to which the airline is willing to contribute (financially) to the programme.

The following costs have to be considered (it is also recommended to budget for additional and ongoing maintenance cost for the required ground-based infrastructure and software):

- Developmental and infrastructure costs
    - AMDAR onboard software
    - Software integration and rollout

  - Communications infrastructure
  - Data processing development
  - Data optimisation system
- On-going operational costs
  - Data communications costs
  - Aircraft system utilisation costs

2.1.1.6 Contracts and agreements between NMHS and airlines

It is very important that an agreement, contract or memorandum of understanding (MoU) is established between the NMHS and each participating airline for the operation of the national or regional AMDAR programme. Such a document should outline the terms and conditions agreed upon to cover at least the following aspects of the programme operation:

- The time period for operation of the agreement and the programme, including an arrangement for contract or agreement termination
- The number of aircraft to be equipped with AMDAR software for reporting AMDAR data at an agreed frequency of reporting (e.g. refer to an included specification of requirements or proposal).
- Costs payable to the airline by the NMHS.
- Requirements of the airline to ensure data supply and quality.
- Requirements of the NMHS to report to the airline any issues or faults associated with AMDAR software performance and data quality
- The terms and conditions, including liabilities and the rights of the NMHS and 3rd parties (e.g. NMHS clients) covering use of the AMDAR data, which may desirably include ownership (i.e. jointly with the airline) of the associated meteorological data upon reception. It is critical that this aspect of the agreement at least allows AMDAR data to be distributed on the GTS and used by WMO Members according to WMO resolution 40[7].
- 3rd party liabilities associated with operation of the programme and AMDAR data use:
  - The NMHS should seek to ensure that the agreement precludes the NMHS from being liable for any damages (including 3rd party claims) associated with any aspect of the aircraft operation (this must be the airline's responsibility); and,
  - The agreement should preclude the airline being liable for damages (including 3rd party claims) associated with any aspect of data use by the NMHS and its data users and clients (this should be the NMHS's responsibility).
- Ownership and Intellectual Property (IP) rights. The agreement might stipulate that:
  - If appropriate and, depending on which party contributed resources to its development, the NMHS has ownership of the AMDAR onboard software.
  - WMO and/or the NMHS have rights over the IP associated with the specification of the AMDAR onboard software.

Important Notes:

The making of contracts and agreements can be a complex process and such documents must be consistent and in keeping with both national and international laws and legislation. For this reason, it is highly recommended that Members consult with either their own or hired legal counsel to assist

[7] *WMO Resolution 40: http://www.wmo.int/pages/about/Resolution40_en.html*

in the agreement development process and ensure that any agreement or contract developed is both compliant with the law and does not unknowingly or otherwise disadvantage any parties to the agreement.

In many cases, national laws prevent contracts from the waiving of 3rd party liabilities. In such cases, it is critical to undertake a risk assessment and ensure that each party has developed and implemented appropriate mitigation strategies for any risks associated with the operation of the programme.

If requested, WMO may be able to assist in the process of developing an agreement or contract between a NMHS and an airline for operation of a new or developing AMDAR programme.

2.1.2 Design and Implementation of the AMDAR system

Comment [36]: Need to add in this section a section on Water Vapour Measurement and WVSS and urge Members to develop WVM as a component of their AMDAR programs.

When commencing a new AMDAR programme, there are many considerations that must be made in regard to the design of the system that will be required to be developed and implemented to support the reception, processing and utilisation of the AMDAR data delivered by the participating airlines.

In designing and implementing the AMDAR system, the NMHS must consider all those components of the AMDAR system that are shown in Figure 1 above. Only summary information on the AMDAR system design will be covered in this guidance.

The following are the major system components that must be addressed, developed and

implemented:

- Regional and international design considerations;
- Configuration and optimisation;
- AMDAR onboard software development and implementation;
- Air-to-ground communications;
- Ground-based communications infrastructure for AMDAR message reception and processing;
- Delivery to data users; and
- Data quality management and monitoring.

2.1.2.1 Regional and international design considerations

There are two regional international aspects of an AMDAR programme design that might be taken into consideration before designing and implementing an AMDAR programme and system. These are:

1. International AMDAR data sharing and optimisation opportunities; and
2. International cooperation on AMDAR system infrastructure.

Many national airlines operate internationally and, therefore, may be capable of producing AMDAR data both within and outside national boundaries, including both en-route data and vertical profiles at airports. This has implications for two aspects of the AMDAR programme. Firstly, if a national airline is not yet ready to participate in the AMDAR programme, it might be possible for AMDAR data to be provided over or within the country by another operational national AMDAR programme. Through a bilateral arrangement or agreement, the recipient NMHS pays the incremental costs to the operational AMDAR programme for providing the data. Secondly, when it comes to the make-up of the AMDAR fleet to be made operational, it is worth considering equipping a combination of domestic, regional and international aircraft fleets, which, when combined with suitable configuration or optimisation (see below) would allow a more comprehensive national and regional coverage. This would have several advantages including an even greater impact on national, regional and global NWP and the opportunity for collaboration and data cost sharing with other NMHSs.

The second regional international consideration may lead to significant opportunities for reducing the costs associated with AMDAR system infrastructure. Because of the international aspect of airline operations and communications and the fact that the AMDAR programme relies on using standardised aviation and meteorological communications protocols (i.e. AEEC ACARS and WMO BUFR), it is possible that AMDAR data can be received and processed by dedicated regional data processing hubs. This offers the opportunity for international and regional collaboration and efficiency dividends in relation to the development of AMDAR programme infrastructure.

Examples of regional cooperation in AMDAR are:

- The E-AMDAR programme (14 airline partners, supported by 31 member states) which provides supplementary global data outside the EUCOS domain through bilateral agreements and as a contribution to the WMO World Weather Watch Programme;
- The US MDCRS programme (7 airline partners), which provides data outside the USA domestic airspace over central and south America; and,
- AMDAR data cost-sharing between Australia and New Zealand.

This activity is strongly encouraged by WMO and can be facilitated through cooperation within WMO Regional Associations (see: REF Section 1.10 above) and communication between the national WMO Aircraft-based Observations Focal Points.

Comment [37]: Need to add paras on focal points in 1.10 - correct reference is to the WMO CPDB

Under the WMO Aircraft-Based Observations Programme (ABOP), Regional Implementation Plans for AMDAR have been or are being developed as a component of the Regional WIGOS Implementation Plans.

2.1.2.2 Network Configuration and Optimisation

Even before AMDAR software is developed, it is necessary to consider the likely size of the national AMDAR fleet and how data production will be configured and controlled. AMDAR Onboard Software (AOS) contains software configuration parameters and functions for optimising reporting based on geographical area, airport or time. When limited to this onboard functionality, AMDAR systems and programmes can have high redundant data levels (up to 50% for large programmes).

Given the significant communications costs associated with the AMDAR system, AMDAR Onboard Software has been specified and developed to respond to "uplink commands", which are able to be transmitted and processed by the onboard ACARS system. Some AMDAR Programmes have then made use of this AMDAR software functionality by developing and implementing ground-based AMDAR Data Optimisation Systems. From flight schedules and optimisation messages from aircraft, these systems can deduce the available AMDAR data, then automatically compile and send uplink commands in order to reconfigure the reporting configuration of the AMDAR Onboard Software in near real-time based on assessment against data reporting and coverage requirements. Such AMDAR Data Optimisation Systems have demonstrated the capability to reduce the communications costs associated with the AMDAR system by 50% or more, while not adversely impacting useful data coverage.

AMDAR Data Optimisation Systems have been implemented in the E-AMDAR and Australian AMDAR Programmes, and ARINC is able to provide this as a service to their AMDAR client NMHSs. SITA is also developing such an application as a potential service to existing and future AMDAR programmes.

For national AMDAR Programmes with fleet sizes of the order of 50 or more aircraft, it is recommended that AMDAR Data Optimisation Systems be implemented as a component of the system.

In addition to reducing costs and data redundancy levels, AMDAR Data Optimisation Systems also offer the capability of altering and adjusting data observational outputs based on short-term requirements. Potential applications include the targeting of additional AMDAR data for synoptic weather system monitoring and prediction, or ensuring coverage during airline strikes and other outages.

The AMDAR onboard software also is configurable so as to control where and when AMDAR data is produced and the default configuration of the software should be discussed with the software developer and specified before the software is developed and released. This may include control over where data is produced geographically and at which airports vertical profiles are generated.

2.1.2.3 AMDAR onboard software development and implementation

The role of the AMDAR Onboard Software (AOS) is to facilitate the functions and the required system interfaces of the onboard AMDAR system. The primary functions of the AMDAR Onboard Software are:

1. Interface to and accept input data from a variety of innate aircraft avionics equipment;
2. Perform initial quality checks on the input data;
3. Perform calculations upon the input data to derive required meteorological variables;
4. At set intervals, process collected data into standard output messages for transmission to ground stations; and,
5. Accept and process inputs, allowing users to alter the AOS behaviour or determine the current configuration.

Given that the full functionality of AOS is computationally complex and demanding, the AMDAR system relies on and is usually best employed in modern, larger commercial aircraft, which will tend to have the necessary avionics, data computers and communications systems.

The current AMDAR Observing System relies on the communications protocols defined for the Aircraft Communications Adressing and Reporting System (ACARS), which are specified within the standards of the Aeronautical Airlines Electronic Engineering Committee (AEEC).

WMO currently specifies and maintains two meteorological standards for AMDAR Onboard Software:

1. The AMDAR Onboard Software Functional Requirements Specification (AOSFRS), which supersedes the ACARS AMDAR ACMS (AAA) specification series (versions 1 to 3).
2. The "ARINC 620" AMDAR Onboard Software versions 1 through 5 defined within the AEEC 620-7 Data Link Ground System Standard and Interface Specification (DGSS/IS), which is maintained by the AEEC Data Link Systems Sub-committee. Within the specification, AMDAR reporting formats and functionality are defined through the definition of the Meteorological Report.

The AOSFRS and the ARINC 620 specifications both rely on the basic DGSS/IS ACARS protocols. The specifications or their URL references are provided from the AMDAR Resources Area[8].

The NMHS and the Airlines will need to reach agreement on the terms and conditions for any software development that is required to be undertaken and whether there will be a requirement for the involvement of a third-party applications developer. The AOS will generally be required to undergo testing and certification with the avionics manufacturer to ensure that it complies with requirements and does not interfere with or adversely affect existing and standard applications.

Further advice and details can be found in the Software Development Guidance for AMDAR (WIGOS Technical Report 2015-XX) (This is Axel's paper).

2.1.2.3.1 Flight testing

Once AOS software has been developed, it should be tested operationally to ensure its correct functionality and performance, including message format, response to uplink command, correct software configuration and the quality of the AMDAR data produced. Arrangements to conduct flight testing on one or more aircraft over a suitable period of time (e.g. 1-2 weeks) should be made

[8] http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/resources/index_en.htm

with the airline and the AOS developer in advance and, if necessary, include a process to correct any software defects or bugs. Such testing can be initiated from the ground during aircraft maintenance but it is recommended to examine the AMDAR data received from a series of operational flights and to analyse the results very carefully before the full AOS roll out occurs and before AMDAR data is transmitted on the GTS. The flight testing process and data analysis should include a number of checks including (as a minimum):

- Comparing temperature, wind and other meteorological data with co-located radiosonde or NWP data; and,
- Validating spatial and temporal coordinates.

Experts from the Aircraft-Based Observations Programme can assist and provide technical advice in relation to AOS specification, development and testing.

2.1.2.3.2 Software roll out

Once the AOS and the data quality have been tested, and the AMDAR data processing system is operationally implemented, the airline can be directed to install the software across the entire proposed AMDAR fleet. This will usually occur during standard aircraft maintenance checks and processes.

2.1.2.4 Air to ground communications

The communications system that supports communications for the global aviation industry is called the Aircraft Communication Addressing and Reporting System (ACARS). The aeronautical communications infrastructure that supports air-to-ground communications of ACARS is normally provided by one of the two major aviation Data Service Provider (DSP) companies (ARINC and SITA)[9]. Independent communications companies are operating similar aviation services in Japan, China, Thailand and Brazil that link to the ground-based component of the global services provided by ARINC and SITA. Both companies provide two-way communications based on VHF, HF and satellite systems. Airlines will usually have a contract with one or more of these companies to provide global communications services for their own commercial operational purposes.

While onboard avionics applications requiring ground communications via ACARS can utilise both VHF and satellite communications systems, AMDAR software applications are generally configured to use only the VHF communications channel for data delivery. This can mean that en-route reports, compiled over locations where VHF coverage is not available, can be delayed by several hours on long-haul international flights.

The AMDAR data are in general sent by the aircraft's ACARS datalink equipment via VHF radio. In geographical areas, where VHF has no coverage, HF radio or satellite communication is used and the communication service is provided by an international Air Transport data-link service provider (DSP) like ARINC and SITA (in some areas like Brazil, China and Japan other national companies provide similar services). As HF radio and, satellite in particular, is more expensive than VHF some airlines may choose to store data onboard until the aircraft reaches an area with good VHF connection. This causes a delay in the availability of the data.

Comment [38]: As for the previous comment, this repeats information from above. Under Operations this section should deal with:

TBD.

Comment [39]: This para duplicates with the one above. one of them should go.

The data are received at the DSP's ground reception system and, with agreement of the airline, data can be routed in parallel to the airline and the NMHS. This would require setting up hardware and software applications to route the data to the NMHS using an Internet transfer protocol like e.g. TCP/IP or FTP. In this case the NMHS will need to negotiate a contract with the DSP for providing the service.

Some airlines prefer to send their data from the aircraft, via the DSP, directly to the airline's ground reception system and then route the data to the NMHS. Also with this solution transfer through TCP/IP or FTP can be used. It is recommendable to set up a dedicated Internet line for this in order to secure a stable connection and to minimise delays in data reception.

[9] Although a new operational system has recently been developed based on the low earth orbiting satellite system IRIDIUM and may also be an optional consideration.

In both cases the data will be received in a Type-B ACARS message format. The NMHS will have to develop a ground processing system for receiving, de-coding, quality checking the data before re-formatting them into a bulletin for operational use and distribution on the GTS.

2.1.2.5 Ground-based reception and processing

Most airlines insist that AMDAR data must be sent directly from the aircraft to their own ground based data reception systems and then transferred to the NMHS. In this case, a method for transferring the data from the airline to the NMHS will have to be agreed upon and implemented. In some cases, the airline will agree to the data being addressed directly to the NMHS from the DSP, in which case it would be necessary to establish a network address and connection with the DSP. In both cases, the data is usually received by the NMHS in the same format as which it is relayed from the aircraft to the ground as a Type B ACARS message.

It is the responsibility of the NMHS to ensure that the necessary ground-based processing system for AMDAR data is developed, implemented and operational by the time the airline(s) commence producing data.

The data acquisition and processing system is normally located in the NMHS and is required to:

1. receive the data (most usually delivered as a Type B ACARS message, for which the format can be obtained from the relevant software specification – AOSFRS or ARINC 620);
2. decode the data;
3. conduct rudimentary data quality checks (range, rates of change, observations consistency etc – see Appendix ?? (= relevant material from ARM Appendix II));
4. reformat the data into acceptable messages/bulletins for operational use within the NMHS and for exchange on the WMO GTS.

2.1.2.6 Instruments and Methods of Observations

- *(Info about the aircraft Avionics (could refer to avionics survey) and Sensors (refer to Chapter 3 in Guide to Meteorological Instruments and Methods of Observation – WMO-No 8)*
- *(This section should reference the AOSFRS in relation to AMDAR onboard software and IMO.)*
- Specification of AOS Requirements
    - AOSFRS
    - ARINC 620

2.1.3 Operations

2.1.3.1 General Requirements

2.1.3.1.1 Responsbilities of Members

Members shall ensure that their AMDAR system is operated in accordance with the following general requirements:

- Put in place agreements with partner airlines to ensure that airlines take responsibility for those responsibilities identified in [REF section 2.1.3.1.2 below] and aircraft-based observations are able to be made available to all WMO Members on the WMO Global Telecommunications system in accordance with the requirements of WMO Resolution 40.
- In consultation with airline partners, configuration of AMDAR onboard software (AOS) in accordance with requirements for upper air data and aircraft-based observations (see [REF section 1.5])

- If utilised as part of the AMDAR programme, ensure configuration and operation of the ground-based optimisation systems in consultation with airline partners.
- Processing of AMDAR messages and observational data received from partner airlines - see [REF section 2.1.3.3].
- Operation of their AMDAR observing system in accordance with requirements for WIGOS Quality Management - See [REF sections 1.7 and 2.1.3.3]
- Quality control of AMDAR observations - see [REF section 2.1.3.3].
- Reporting of aircraft-based observations observational and metadata in accordance with national, regional and international requirements and for provision of such data on the WMO Global Telecommunications System - see [REF sections 1.8, 2.1.3.4 and 2.1.3.5].
- Monitoring of operational systems and observational data (see [REF sections 1.7 and 2.1.3.3]
- Management of incidents, including the identification and rectification of faults - see [REF 2.1.3.6].
- Maintenance of the observing system components - see [REF 2.1.3.8]
- Planning, implementation and documentation of changes in the operational practices and procedures of the observing system - see [REF 2.1.3.7]

2.1.3.1.2 Responsiblities of Partner Airlines

Partner airlines have several responsibilities to facilitate and support the planning and operation of an AMDAR Programme and these responsibilities should be negotiated in a formal agreement as described in section 2.1.3.1.1. They include:

- Assist in developing AMDAR Onboard Software as needed, see (REF section 2.1.2.3)
- Develop documentation to support AMDAR Onboard Software installation and maintenance
- Assist in flight testing of the software, see (REF section 2.1.2.3.1)
- Implement the software in avionics systems through roll-out on the selected fleet(s), see (REF section 2.1.2.3.2)
- Arrange for air to ground communication of AMDAR data to the Member, see (REF section 2.1.2.4)
- Facilitate contacts between Members and Data Service Provider(s) as needed, see (REF section 2.1.2.4)
- Assist in setting up ground to ground data transmission as needed, see (REF section 2.1.2.5)
- Allow the Member the use or ownership of data for Member mandated purposes according to WMO Resolution 40.
- Ensure that updates to avionics system do not disable or adversely affect AMDAR.
- Provide metadata; see (REF sections 1.9 and 2.1.3.5).
- Rectify sensor issues as soon as possible within operational constraints
- Inform about planned operational changes e.g. of time tables, routes, fleet changes or renewals and other issues that could influence AMDAR
- Charge all costs at reasonable (incremental) level.

2.1.3.1.3 Responsibilities of Other Partners

Organisations providing support to the AMDAR operations are defined as Other Partners. Members and airlines may have to contract a data service provider (DSP) for the transmission of AMDAR data from the aircraft to the ground and from the airline's data processing infrastructure to the NMHS. The contract should:

- Guarantee the highest possible reliability of the transmission infrastructure operated by the DSP, see (REF sections 2.1.2.4, 2.1.2.5 and 2.1.3.2.4)

- Include a feed-back structure to inform the Member and the airline about any planned changes or incidental issues that will disrupt the data transmission
- Define back-up solutions needed to minimize the time of disruption in data provision.

2.1.3.2 Observing Practices

2.1.3.2.1 Reporting Configuration

2.1.3.2.1.1 Observing Frequency

Members shall be responsible, in collaboration with partner airlines, for ensuring that AMDAR onboard software is configured optimally so as to best meet requirements for upper air data and aircraft-based observations as described in [REF section 1.5].

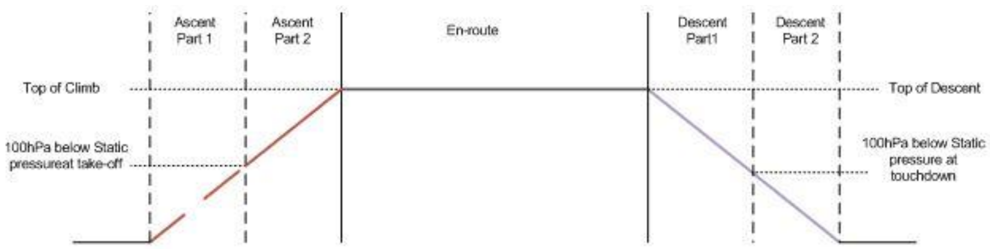
As described in [REF section 2.1.2.3], currently, the primary standard for AOS is the AMDAR Onboard Software Functional Requirements Specification (AOSFRS), maintained by WMO [REF AOSFRS]. The AOSFRS provides the functional and meteorological requirements for AOS that also should underpin any applications that adhere to the uplink and downlink message formats associated with the AEEC ARINC 620 Meteorological Report.

Depending on the degree of configurability of the AOS that has been implemented (see [REF section 2.1.2], Members should collaborate with partner airlines to ensure that the AOS reporting configuration is established and maintained so as to best meet the default reporting regime defined within the AOSFRS as a minimum.

The AOS should be used to configure and determine both the frequency of reporting during the various phases of flights and also over which geographical areas and locations the observations are to be made and reported.

The reporting frequency during the ascent, en-route and descent phases of a flight shall be in accordance with the AOSFRS as a minimum, either based on air pressure level specification (vertical resolution) or on a time-based specification (temporal resolution).

AMDAR Flight Phases:



AMDAR Observing Intervals by Flight Phase:

	Pressure Based Scheme	Time Based Scheme
Ascent Part 1	5 or 10 hPa intervals for first 100 hPa (default 10 hPa)	3 to 20secs intervals (default 6) for 30 to 200secs (default 90)
Ascent Part 2	25 or 50 hPa intervals above first 100 hPa (default 50 hPa)	20 to 60secs intervals (default 20) for 490 to 1050secs (default 510)
En-route:	1 to 60 minute intervals (default 7)	
Descent Part 1	25 or 50 hPa intervals from TOD to last 100 hPa (default 50 hPa)	20 to 300secs intervals (default 40) from top of descent to touchdown.
Descent Part 2	5 or 10 hPa intervals for last 100 hPa (default 10 hPa)	

2.1.3.2.1.2 Reporting Location and Optimisation

Ideally vertical profiles of AMDAR observations at airports would be equally spaced (both geographically and temporally) and configured or optimised so as to best meet requirements associated with the relevant Application Area(s) for which the AMDAR network has been established to address (see [REF 1.5]. For example, the AMDAR network might be configured and optimised so as to endeavour to meet the requirements for provision of upper air data or Global NWP. However, in reality and in practice, the ideal situation is very difficult to attain. Airports are located where they are needed for reasons of transport of people and goods. In some areas they are more close to each other than would be needed from the observational point of view and in sparsely populated areas there are long distances between airports. Furthermore, an airline cooperating in an AMDAR programme might not serve all airports needed to deliver the required horizontal coverage of vertical profiles.

The geographical production of observations within the AOS can be controlled through two mechanisms ideally available within the AOS application and as defined within the AOSFRS standard. Firstly geographical boxes can be defined and set either to report or supress observations. Secondly, a list of airports can be defined and set either to report or suppress vertical profiles. Members should collaborate with airline partners to ensure that these configurations are established and maintained so as to best meet the requirements for horizontal resolution of reporting of both vertical profiles and enroute AMDAR observations.

Ground-based Data Optimisation Configuration

Once the AOS is configured the aircraft will make observations and send reports in the same way during each and every flight. The permanent configuration settings can be changed but that requires either a manual intervention, usually by the airline. As a result, and depending on number of aircraft in the AMDAR fleet and their flight schedules, this may result in the collection of more data than required at certain airports or along certain routes. These redundant data may be up to fifty percent or more of the total volume of AMDAR data collected and can result in high and unnecessary costs for the NMHS. This issue can be alleviated or resolved through the development and employment of a ground-based data optimisation system. More details on the development and implementation of an optimisation system is provided in [REF section 2.1.2.2].

If Members employ an optimisation system, they should:

- Configure or arrange for configuration of the system to ensure that they optimally meet requirements for provision of aircraft-based observations as described in [REF section 1.5];
- Collaborate and cooperate with regional Members and other AMDAR programmes to endeavour to optimise regional and global coverage of aircraft-based observations outside and beyond national borders - see [REF sections 1.10 and 2.1.2.2]

Comment [40]: These statements relate to design and repeat or add to material from the section above (2.1.2.2).

Under operations, this section should deal with the following:

- Network operations, maintenance and monitoring.
- Identification and rectification of issues (refer to Incident Management). Configuration of the optimisation system according to requirements.
- Maintenance of the optimisation system

2.1.3.3 Quality Management

2.1.3.3.1 Data Quality Control

Onboard data

Quality control processing shall be applied to AMDAR observational data variables according to the data validation procedures as specified in the [REF AOSFRS, Chapter 3].(CIMO IOM No. 115).

Ground-based Data Processing

Members shall as a minimum comply with the requirements for quality control of aircraft meteorological observations as defined within the Manual on GDPFS, Part II, Annex II.1, Minimum Standards for Quality Control of Data for Use in the GDPFS.

Members should apply the following quality control procedures to AMDAR data after reception in the processing center. The message elements and variables in each observation shall be subjected to the following validity checks:

1. A range check shall be applied based on Table 2.1.3.3.1(1) below.
2. Processed into a WMO bulletin following the binary FM94 encoding, according to the most recent BUFR Template (Manual on Codes, WMO No. 306)
3. Insert the AMDAR bulletin into the GTS as soon as available, in accordance with the WMO GTS requirements (Manual on the GTS, WMO No. 386) .

In validity checking, as a first step, gross errors should be identified. The table below gives guidance:

Data values falling outside the 'range' intervals given in the table below or already flagged in the aircraft data acquisition system shall be considered invalid.

Element	Unit	Range
Pressure Altitude	Foot (ft)	-1000 to 50000
Static Air Temperature	^{o}C	-99 to 99
Wind Direction	^{o} from true N	1 to 360
Wind Speed	Knot (kt)	0 to 800
Latitude	Degree:minute	90:00S to 90:00N
Longitude	Degree:minute	180:00E to 180:00W
Time (UTC)	Hour:Minute:Second	00:00:00 to 23:59:59
Turbulence (g)	g	-3 to 6
Turbulence (DEVG)	ms^{-1}	0 to 20
Turbulence (EDR)	$m^{2/3}s^{-1}$	0 to 1

Comment [41]: Possibly add a section on Airline responsibility for upstream quality control processes.

Comment [42]: Reference to the ASOFRS should be made to the most current version only and not to a specific version.

Comment [43]: 1. Require general requirements for QC of data: Reference Manual on GDPFS

2. Require specific QC for AMDAR

AMDAR Reference Manual - Appendix IV - copy and paste if possible.

Need to ensure that we have a list of QC checks to be performed on incoming AMDAR data before it is encoded in BUFR for the GTS.

Comment [44]: Work in progress: Require development of standardised QC procedures.

Comment [45]: Table comes from the ARM - checked by Stig against the AOSFRS.

Comment [46]: Check range values and decide on values.

Comment [47]: Uits MUST be in SI for reg material. Here: m

Comment [48]: Units must be in SI; here: m/s

Comment [49]: currently, requirements are sted in decimal degrees, not deg-min-sec

Humidity (RH)	%	0 to 100
Humidity (dew pt)	°C	-99 to +49
Humidity (mixing ratio)	gram/kg	0 to 100

Comment [50]: 0 should not be used

Note: Time (UTC) should be checked routinely against the aircraft master clock.

Several other quality checks have to be performed on incoming AMDAR data before they are encoded and transmitted on the GTS. Further information is in the Annex XX (this refers to a relevant update of ARM Annex IV)

2.1.3.3.2 Data monitoring and quality assessment

WMO Members shall develop and implement policy and procedures for quality monitoring and quality assessment of AMDAR observations made by their AMDAR programme.

Comment [51]: There may be a future requirement to develop additional guidance on QM best practice.

The WMO Lead Center on Aircraft Data is responsible for quality monitoring of aircraft-based observations and the dissemination of monitoring information to WMO Members.

Current requirements for the monitoring of aircraft data by monitoring centers are defined in the Manual on the Global Data-Processing and Forecasting System (GDPFS Part II, Attachment 9, Section 5 on Aircraft Data).

The World Meteorological Centre, Washington, has the role as Lead Centre for Aircraft Data with the data monitoring processes carried out by the US National Weather Service, National Centers for Environmental Prediction, Central Operations.

At the current time, aircraft and AMDAR data monitoring is limited to the compilation and notification of monthly Numerical Weather Prediction (NWP) comparison reports that are available online from: NCEP Central Operations, Quality Assessment Project: http://www.nco.ncep.noaa.gov/pmb/qap/

Members shall use the monitoring information and reports provided by the WMO Lead Center for Aircraft Data as an integrated component of the quality management operations of their AMDAR programme.

Members should consider the development and implementation of additional monitoring procedures for AMDAR observational data, which might include:

- Use of statistics and diagnostic results from their AMDAR quality control procedures (see [REF section 2.1.3.3.1].
- Use of the monitoring results of other WMO Member monitoring centers.
- Inter-comparison of AMDAR observations with NWP fields.
- Inter-comparison of AMDAR observations with other sources of upper air observations, for example radiosonde data.
- Monitoring diagnostics developed and based on other data analysis techniques such as:
  - Temporal consistency/gradient checks.
  - Spatial consistency/gradient checks.
  - Aircraft inter-comparison.

Members shall develop procedures for the analysis of available monitoring information and take prompt and appropriate corrective action (see [REF 2.1.3.6]) for systemic faults and issues identified that adversely affect the quality of aircraft-based observations transmitted on the WMO GTS.

2.1.3.4 Data Management and Reporting

AMDARDM can be viewed within the context of the WMO World Weather Watch Data Management (WWWDM) programme. The concept of WWWDM is one of carrying out those activities required to optimise the integration of the Global Observing System (GOS), Global Telecommunications System (GTS) and Global Data Processing System (GDPS). WWWDM functions include:

(i) Providing specifications for data representation, including codes and exchange formats, guidelines for the design of databases and storage of observational data and processed information.

(ii) Defining and designing proper procedures and interfaces, particularly in the area of data processing and telecommunications, to allow Members to obtain the coherent and appropriate sets of data and products required, despite the disparity in the levels of sophistication of technology and techniques of various WWW centres.

(iii) Monitoring of AMDAR operations and the quality of basic data and output products.

In order to meet, as far as possible, the requirements of WMO global and regional programmes and allow for the more stringent requirements of national programmes, data requirements have been developed that define:

(i) The elements to be reported in a single observation, their ranges and resolution

(ii) The intervals in space and time between each observation.

(iii) The recommended averaging times for specific elements reported according to operational environment (eg phase of flight)

(iv) The recommended data compression schemes to be employed to minimise transmission time (and therefore cost)

(v) The recommended data selection options for space and time including route and airport selection

(vi) The recommended output code formats for widespread data dissemination on the ground (e.g. GTS distribution)

Elements to be reported in a single observation are summarised as follows:

(i) Latitude

(ii) Longitude

(iii) Time

(iv) Pressure altitude

(v) Temperature

(vi) Wind direction

(vii) Wind speed

(viii) Turbulence

(ix) Humidity

(x) Icing

(xi) Phase of flight

(xii) Roll angle or roll and pitch angle

(xiii) Aircraft identifier.

Further details (including units, range, reported resolution and desired accuracy as well as formats for downlinking the data) are given in Appendix XX (this refers to ARM Annex II that has to be

Comment [52]: Things to resolve in this section:

- Move to section in Chapter 1?
- Reporting of FM42

Comment [53]: Text from the ARM.

Jitze to revise.

In relation to migration to BUFR - refer to: http://www.wmo.int/pages/prog/www/WMOCodes/MigrationTDCF.html

Find the document on use of BUFR templates for encoding AMDAR/ABO

Ensure that statements are clear that the BUFR AMDAR Template V7 should be used for all ABO data transmission on the GTS.

reviewed for relevance). Refer also to the CIMO IOM Report No 115 AMDAR Onboard Software Functional Requirements Specification.

Data are circulated globally on the WMO Global Telecommunications System (GTS). The GTS code forms that have been in common use are:

(i) Alpha-numeric AMDAR code (WMO Code FM42 –XI Ext). The use of this code is discontinued.

(ii) Binary (BUFR) AMDAR code (WMO Code FM 94). From 11 November 2014 it is mandatory to use only the BUFR code. The BUFR Template to be used is found (add correct reference here).

Downlinked data must be converted to the BUFR format before insertion into the GTS.

2.1.3.5 Metadata Management and Reporting

Metadata are "data about data" or in other words information that describes the observational data in such a way that the user can decide whether the data are suitable for the user's intended purpose.

The WIGOS Metadata Standard specifies 10 Core Metadata Categories covering both organisational and technical aspects of data ranging from purpose of observations till reporting and ownership of data. Each Core Category contains a set of specific elements (either mandatory or optional/conditional) for reporting to the extent they are relevant for AMDAR data.

Comment [DL54]: (is there any later reference to a finalised document than this: see ICG-WIGOS/TT-WMD-2/Doc.5 from May 2014)

Metadata should be reported to the WMO Information System (WIS) to facilitate the use and interpretation of AMDAR data. Some of the metadata can be defined by an AMDAR programme but several of the metadata are airline and aircraft specific and the AMDAR programme has to collect these from the cooperating airlines.

The reporting format for AMDAR data is under preparation.

2.1.3.6 Systems Operations and Management

An operational AMDAR system will have several important communications and data processing components, which may include one or more of:

- A networked data reception computer or server that receives AMDAR data from a aviation Data Service Provider (DSP), airline or other data provider entity.
- A message switching/routing computer or server.
- A data processing computer system.
- A data archival or database computer system.
- If optimisation/uplinking is implemented, a networked computer or server that sends AMDAR uplink commands to the aviation DSP or airline. As the uplink messages are able to change the configuration of aircraft systems, the data link to the DSP or airline should implement VPN/encryption.

Comment [55]: I think the "message switching" should be briefly explained

Members should ensure that they develop and implement policy, plans and procedures for each of the AMDAR component systems so as to ensure that their operation is maintained and ensured at the highest possible level of availability and in order to meet both national and international requirements for the continuous and uninterrupted provision of AMDAR data products.

Members should ensure that systems management policy and procedures includes suitable provisions for such measures as:

- Computer system redundancy (hot or warm stand-by).
- System fault and maintenance switch-over.
- Message and data buffering, archiving and backup.
- Database mirroring or replication.

- Computer hardware, operating system and applications software maintenance.

2.1.3.7 Incident Management

An incident is an unplanned interruption or reduction in quality of a service. Failure of a configuration item that has not yet affected service is also an incident. Incident management is the process of any unplanned interruption to recover as quickly and effectively as possible. The objectives include:

- Recover as quickly as possible to the normal service production and minimize the negative impact for the users;.
- Ensure that the highest possible levels of service quality and availability are met.

Incidents refer to situations that occur often at short notice and might have a time limited adverse effect on an AMDAR programme in reducing its capability to produce data to its normal extent. Examples of incidents that will have an negative effect on the production of AMDAR data:

  - malfunction of e.g a temperature sensor of an aircraft. This information has to be reported back to the airline as soon as possible with a request to have the sensor replaced as soon as practicable. The aircraft has to be blacklisted and the data prevented from being processed to the GTS.
  - industrial actions by airline staff (usually announced a few days in advance);
  - unplanned grounding of a number of aircraft for technical or operational reasons;
  - updates of avionics software that disturbs the proper functioning of the onboard AMDAR software.

It is recommended that the Programme Manager responsible for the affected AMDAR programme informs the AMDAR Focal Points and other operational AMDAR programmes as well as International Data Monitoring Centres (link), describing the incident and the possible actions taken in order to minimize the effect on the AMDAR data provision. If available, a time indication should be added at which the status is brought back to the situation prior to the start of the incident.

2.1.3.8 Change Management

Change management in an AMDAR programme means defining and implementing procedures and/or technologies dealing with improvements in the service environment and to profit from the changing opportunities.

In contrast to incident a change is seen as a situation that is planned and that will influence an AMDAR programme for a pre-defined time and therefore might reduce the programme's capability to produce data to its normal extent if no optimisation system is available. Examples of such changes are:

- an airline stops serving a certain geographical area that is part of the AMDAR programme
- an airline retires a certain aircraft type of its fleet and there is no AMDAR onboard software available for new aircraft types.
- the AMDAR onboard software needs to be replaced by an updated version (this change and the date when it is implemented should be re-encoded in the metadata).
- the AMDAR programme will change to a different BUFR Template in its bulletins on GTs

To inform the AMDAR stakeholders about the (foreseen) disruptions in the level of service caused by changes in the national/regional AMDAR programme, the Programme Management shall act in the same way as for Incident Management

2.1.3.9 Maintenance

A minimum level of maintenance for supporting the required or improved service environment is necessary for the majority of the elements in an AMDAR programme. Maintenance of the aircraft, its sensors and avionics hardware and software is considered to be the responsibility of each cooperating airline. Similarly for the airline's ground processing system when the AMDAR data is passed through that system to the NMHS.

Humidity sensors installed in aircraft of participating airlines are the property of the NMHS unless otherwise is agreed between an airline and the NMHS. Routine maintenance and (re)calibration will have to be carried out in accordance with the maintenance scheme provided by the manufacturer of the humidity sensor. Maintenance will normally imply the replacement of the sensor for which the opportunity and the conditions of the labour involved will have to be negotiated between the NMHS and the airline.

In case of a sensor failure the NMHS shall agree with the airline the soonest opportunity and the conditions of the labour involved, not taking into account the maintenance and replacement scheme provided by the sensor manufacturer.

Additionally the Programme Management shall inform the AMDAR stakeholders about the (foreseen) disruptions in the level of service caused by changes in the national/regional AMDAR programme, in the same way as for Incident Management.

The NMHS is responsible for sending the humidity sensor to the sensor manufacturer for repair, maintenance and/or (re)calibration. After return of the humidity sensor, the sensor will be put in stock as spare.

Maintenance of the AMDAR onboard software shall be initiated by the owner of the software either at initiative of the owner or on request by WMO. Software maintenance will be needed in case of detected software errors ("bugs") or a change in the software requirements specification. Any software change shall be communicated to the AMDAR Focal Points.

The NMHS is responsible for the maintenance of its ground based infrastructure necessary for receiving, processing and distributing the AMDAR data and for the monitoring of the quality of the data and products.

- Inspection and Supervision Not relevant here. This is for the airlines ??? Reference can be made to specific ICAO docs on inspection of aircraft
- Calibration Procedures This should be in 2.3 Instrumeents etc ??? Reference to CIMO Guide and ICAO to follow ISO 17025 requirements on sensor calibrations.

Comment [56]: This is responsibility for the airlines

Comment [57]: This would fit better in the chapter on Instruments and methods of observation

2.1.4 Capacity Development and Outreach

The work programme of the CBS and CIMO Expert Teams includes activities for training and outreach in regard to the technical details of implementing an AMDAR programme and the use and management of AMDAR data.

2.1.4.1 Regional AMDAR Workshops

AMDAR workshops should be initiated under an agreement between WMO and a hosting WMO Member and should be organised following the General Terms & conditions for Hosting a WMO Regional Workshop on AMDAR (Reference needed). For efficiency reasons the organisation of a regional workshop is preferred. The purpose of the workshop is not only to assist Members and their staff to start an AMDAR programme but also to stimulate a wider development of AMDAR in the region.

The workshop programme covers presentations made by the WMO Secretariat and invited AMDAR experts and discussions on the various aspects of planning, implementation and operation of an AMDAR programme. The programme also includes presentations highlighting the benefits of AMDAR data to meteorology and to aviation.

Workshops have been held in the following countries:

South Africa, October 2003 for the South African Society for Atmospheric Sciences (SASAS)

Hungary, December 2004 for Central and Eastern Europe

Romania November 2007 for South-East European countries

Malaysia, November 2008 for South-East Asia

Mexico, November 2011 for Latin America

2.1.4.2 On-line interactive training course

An on-line Learning Module on AMDAR is made available through a contract with the COMET Program of the University Corporation for Atmospheric Research (UCAR).

The Learning Module starts with an Introduction to AMDAR and continuous with a question and answer session where experts provide the information on several applications benefitting from the use of AMDAR data. The experts represent the meteorologists (numerical weather prediction, forecasting, forecast verification and climate research), the airlines (safety and economy of operations) and the AMDAR systems manager,.

The Learning Module on AMDAR can be found as part of the COMET's MetEd freely accessible collection of learning resources for the geoscience community. Among these resources is also the module on volcanic ash describing impacts to aviation, climate, maritime operations and society and includes training for forecasters.

The COMET learning resources can be found at http://www.comet.ucar.edu under the MetEd heading.

2.1.4.3 WMO AMDAR Website

WMO maintains an AMDAR website (http://www.wmo.int/AMDAR) providing information on the AMDAR Observation System, including statistics, AMDAR resources material, information on the various national and regional AMDAR programmes. The site also provides access to the News, Events and E-mail groups.

2.1.4.4 Newsletter

The WMO AMDAR Newsletter is published twice a year and contains new technical developments and information on the various national and regional AMDAR Programmes

(https://sites.google.com/a/wmo.int/amdar-projects-and-collaboration/email-groups/newsletters-and-news).

Publications

Comment [58]: Add material and number as a sub-section.

The ET-ABO is stimulating and supporting technical and scientific studies resulting in technical reports, reseach publications and presentation material reflecting the benefits of the use of AMDAR data in the several application areas related to operational meteorology and airline operations.

2.1.4.5 Focal Points

Comment [59]: Eventually should link to the WMO CPDB.

Aircraft-based Observations National Focal Points

Members have been asked to nominate contact persons for matters related to AMDAR:

http://www.wmo.int/pages/prog/www/CBS/Lists_WorkGroups/CBS/cross-cutting/amdar-fp

Operational AMDAR Programmes Focal Points

Programme Managers of the operational national and regional AMDAR programmes can be found at http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/programmes/AMDAR_Programmes.html.

2.2 ICAO ABO Systems

Comment [60]: (This section should briefly describe and reference the ICAO systems that lead to the generation of ICAO aircraft observations. Need to pick out the headings from 2.1 that might be relevant here. We will probably need help on this section. Siebren de Haan might be a possible contact.)
(These are not specific separate systems)

ICAO Doc. 4444 PANS/ATM, Air Traffic Management, contains specific paragraphs on the data distribution of observataional data. Of particular relevance are the paragraphs:

- 4.11 POSITION REPORTING

- 4.12 REPORTING OF OPERATIONAL AND METEOROLOGICAL INFORMATION

This document also informs on forwarding of meteorological information:

- [4.12.6.1] When receiving ADS-C reports which contain a meteorological information block, air traffic services units shall relay the basic ADS-C and meteorological information blocks and aircraft registration without delay to the world area forecast centres (WAFCs).

Note.—*Specifications concerning the format to be used in the relay of meteorological information to the WAFCs arecontained in the Manual on Aeronautical Meteorological Practice (Doc 8896).*

- [4.12.6.2] When receiving special air-reports by data link communications, air traffic services units shall forward them without delay to their associated meteorological watch office and the WAFCs.

- [4.12.6.3] When receiving special air-reports by voice communications, air traffic services units shall forward them without delay to their associated meteorological watch offices.

The Manual on Aeronautical Meteorological Practice (Doc 8896), Chapter 7, AIRCRAFT OBSERVATIONS AND REPORTS, provides details on the management of air-reports. It is stated that:

[7.7.2] Air traffic services and meteorological authorities must establish appropriate arrangementsto ensure that routine and special air-reports reported to ATS units by aircraft in flightare transmitted without delay to the world area forecast centres (WAFCs) and to the associated MWO.

[7.7.3] Additional exchange of air-reports beyond WAFCs

Air-reports exchanged beyond WAFCs are considered as basic meteorological data and therefore their further dissemination is subject to WMO provisions. An example of a dissemination pattern of air-reports is shown in Table 7-4.

Table 7-4. Dissemination pattern of air-reports
("→" indicates the centre(s)/office(s) to which the air-report received is to be transmitted)

		Type of air-report received at the ATS unit		
		Routine by air-ground data link	*Special by air-ground data link*	*Special by voice communications*
Dissemination	*Initially by ATS unit*	→ WAFCs → MWO	→ MWO → WAFCs	→ MWO
	Subsequently by MWO		→ VAACs[1]	→ WAFCs → VAACs[1] → MET offices[2] → MWOs[2]

1. Only special air-reports of pre-eruption volcanic activity, volcanic eruption or volcanic ash cloud.
2. To be disseminated in the same way as SIGMET messages (i.e. to MWOs and other MET offices in accordance with RAN agreement) **only if** the special air-report does not warrant issuance of a SIGMET.

.

Further details on delivery of data is in ICAO Doc 9377 , Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services, in particular in paragraph 4.2 REPORTS OF AIRCRAFT OBSERVATIONS RECEIVED IN ATS UNITS. Distinction is made between the voice communications environment and the CNS/ATM systems environment.

Air-reporting: action required by the parties involved

Comment [61]: Taken from 9377.

Pilots: CNS/ATM systems environment

- When automatic dependent surveillance (ADS) or secondary surveillance radar (SSR) Mode S is being applied, routine air-reports are part of the reporting contract which is controlled by the ATS.
- With regard to special air-reports, it is essentialthat pilots initiate a special air-report when special conditions are encountered or observed:

Pilots: voice communications environment

- Aircraft not equipped with air-ground data link are altogether exempted from making routine aircraft observations. This exemption was introduced in view of the availability of a large number of routine aircraft observations through the WMO aircraft meteorological data relay (AMDAR) system.
- Special voice reports, however, will continue to be required whenever the D-FIS application is not available and whenever conditions listed under 4.2.4 are encountered. Detailed instructions for reporting are included in the MODEL AIREP SPECIAL form in Appendix 1 to the PANS-ATM.
- Finally, it should be noted that the requirement for written post-flight reports continues for volcanic ash but has been deleted for all other phenomena

Comment [62]: relevant statement!

ATS personnel: CNS/ATM systems environment

- In the CNS/ATM systems environment, the requirement to make routine air-reports will be met by sending ADS or SSR Mode S reports with the basic ADS/SSR Mode S data block combined with the meteorological information data block. The appropriate ATS authority must ensure that the ADS/SSR Mode S contract is such that the meteorological information is provided every 15 minutes during the en-route phase and every 30 seconds during the climb-out phase for the first 10 minutes of the flight.
- There will be no exemptions in the CNS/ATM systems environment. However, designation procedures may be prescribed in individual regions by regional air navigation agreement for flights on routes with high-density air traffic (e.g. organized tracks). Such designation procedures to be applied by ACCs, i.e. the FIRs and times for which the term “high-densityair routes” is applicable, must be identified by the ICAO regional planning and implementation groups concerned and included in the SUPPS-Air Traffic Services and SUPPS-Meteorology partsof Doc 7030. It is envisaged that one aircraft per air route and per flight level from among those aircraft operating on these high-density air routes will be designated, at approximately hourly intervals, toreport to the ACC concerned.
- In addition to the requirement to establish an ADS/SSR Mode S contract with the appropriate reporting frequency, the ATS authority concerned is obliged to route the relevant blocks of the ADS/SSR Mode S message (i.e. the basic ADS/SSR Mode S data block and the meteorological information data block) automatically to WAFCs London and Washington and to their associated MWOs. Since the routing and processing of messages will be carried out by automated computerized communications systems, the ATS authority concerned need only ensure that the addresses of the WAFCs and the associated MWOs are included in the software and that the computer programme strips off the unnecessary blocks of the full ADS/SSR Mode S message (leaving only the basic ADS/SSR Mode S and meteorological information data blocks) before transmitting it to the WAFCs and MWOs. On receipt of the air-reports, the WAFCs will make them available to States, as necessary, through the WMO global telecommunication system (GTS), as basic data. It may also be noted that routine air-reports are increasingly being used in automated ATM systems (i.e. for accurate flight trajectory forecast purposes).
- With regard to special air-reports in the CNS/ATM systems environment, ATS personnel have a two-fold responsibility:

  a) to pass on the information to other aircraft concerned (for details on the methods to be used in the CNS/ATM systems environment, see 4.2.13); and

  b) to route the information to the associated MWO and to WAFCs London and Washington.

  It is essential that, in addition to the WAFCs, the associated MWO be included as an addressee in the telecommunications software since the issuance of SIGMETis largely based on the timely receipt of special air-reports.

ATS personnel: voice communications environment

- On receipt of special air-reports through voice communications, ATS personnel should compile a message and send it without delay to their associated MWO. To assist inthe compilation of this message and to ensure a standard structure, instructionshave been included in Appendix 1 to the PANS-ATM.
- ATS personnel must ensure that special air-reports are passed on to all aircraft concerned without delay. Special air-reports should be treated asthe equivalent of SIGMET until such time that a corresponding SIGMET, superseding the special air-report, is received from the associated MWO.

MET personnel: CNS/ATM systems environment

- MWOs and local meteorological offices receiving routine air-reports use them as any other basic meteorological data (e.g. upper-air soundings); no ICAO provisions exist concerning their use. The aeronautical requirement to use routine air-reports as briefing material has been deleted from Annex 3.

- On receipt of special air-reports, the MWO has two options:

  a) to issue corresponding SIGMET information; or

  b) to decide that the issuance of SIGMET information is not warranted and to so inform the ACC/FIC (e.g. the phenomenon concerned is of a transient nature).

  In the former case, no further distribution of the underlying air-report is required; in the latter case, the MWO has to disseminate the special air-report in the same way as a SIGMET for a period of sixty minutes after its issuance to ensure that recipients, including the ACCs/FICs concerned,are aware that the phenomenon has been reported by an aircraft.

MET personnel: voice communications environment

Note.— ***No routine air-reports by voice communications are issued.***

- Special air-reports received by the MWO through voice communications must be routed without delay to WAFCs London and Washington. Furthermore, as in the case of special air-reports received through data link, the MWO must decide whether or not the special air-report warrants the issuance of SIGMET information. If it does not, the special air-report itself must be distributed in the same manner as SIGMET information and the ACC/FIC informed accordingly.
- Finally, if the MWO receives a special air-report related to pre-eruption volcanic activity, volcanic eruptions or volcanic ash cloud, it has the additional obligation to transmit that message without delay to the associated VAAC.
- Table 4-1 summarizes the action to be taken on air-reports received by ATS units.

Table 4-1. Action to be taken on air-reports received by ATS units

Action	*Air-reports*		
	Via data link (CNS/ATM environment)		*Via voice communications*
	Routine	*Special*	*Special*
Received in:	ATS data link centre	ATS data link centre ACC/FIC APP/TWR	ACC/FIC[1)] APP/TWR
Used by:	—[2)]	ACC/FIC[3)] APP/TWR[4)]	ACC/FIC[3)] APP/TWR[4)]
Relayed to:	MWO[5)] WAFCs[5)]	MWO[5)] WAFCs[5)]	MWO WAFCs[6)]

Notes:

1) *Special air-reports may be received by an air-ground control radio station related, in particular, to certain ACCs/FICs. All the special air-reports received by such a station must be transmitted without delay to the ACC/FIC concerned and to the MWO associated with the ACC/FIC.*
2) *Air-reports (e.g. winds reported from the climb-out phase of flight) could be used in ATM automated systems for the sequencing of aircraft approaches.*
3) *Pass on all special air-reports received to all aircraft concerned until the ACC/FIC receives the corresponding SIGMET superseding the special air-reports, or for a period of 60 minutes.*
4) *Pass on all special air-reports received (including non-routine reports) to all aircraft concerned, for a period of 60 minutes.*
5) *Automatic relay by the ATS data link centre.*
6) *The MWO or the meteorological authority arranges for the transmission of the air-reports to WAFCs.*

AIREPS

PIREPS

ADS-C (FANS)

Comment [63]: suggested text

Comment [64]: Comes from PANS 4444.

Comment [65]: Contact Randy Stone re systems that produce AIREPs and PIREPs

ADS-B

Mode-S

2.3 Other ABO Systems

Comment [66]: (Suggest that this section may not actually refer specifically to 3rd-party ABO systems but provides general requirements and guidance. Need to pick out the headings from 2.1 that might be relevant here.)

2.3.1 Introduction

When implementing an ABO system, the use of an AMDAR software package in accordance with the latest AOS Functional Requirements Specification shall be preferred. Only if such software package cannot be installed because of absence of the appropriate aircraft infrastructure or Aircraft Onboard Software (e.g. the unlikelihood of developing such software package for financial-economic reasons) the replacement by another ABO system is to be considered. Other ABO systems are commercially available. Advice and guidance can be requested through the WMO Aircraft-based Observations Programme or the national AMDAR Focal Point (link)

2.3.2 Requirements

The installation of another ABO system requires the following specific regulations and specifications.

2.3.2.1 Requirements of Members

If an agreement between the Member and the provider of another ABO system on the distribution of the data on the GTS according to WMO Resolution 40 is in place, the member is required to follow the rules and regulations for encoding and formatting the data, as described in the Manual on Codes, WMO No. 306, before insertion onto the GTS. The Member shall also follow the requirements for data management, metadata management and quality management, as referred to in Section 2.1.3.

2.3.2.2 Requirements of Operators

Operators are defined as the providers of other ABO systems and are required to provide systems generating data which are in conformance with the requirements for Upper Air Data (reference Section 1.5).

2.3.3 Observing Systems

Currently two other operational ABO systems are commercially available. See also Section 1.6.3 for more details.

2.3.3.1 TAMDAR

The Tropospheric Airborne Meteorological Data Reporting system (TAMDAR) is developed in the United States for installation on regional and smaller General Aviation aircraft and is operated by Panasonic Avionics (reference CIMO Guide WMO No. 8, Aircraft-based Observations).

2.3.3.2 AFIRS

The Automated Flight Information Reporting System (AFIRS) was developed in Canada for providing aircraft voice and data services using a global satellite network as the means of communication. The various types of the AFIRS system were developed by FLYHT Aerospace Solutions Ltd. (reference http://flyht.com/products/).

ANNEX IV

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World Meteorological Organisation

Guidance on AMDAR Onboard Software Development

Commission for Basic Systems
Expert Team on Aircraft Based Observing Systems

Version 1.0, December 2014

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1. INTRODUCTION

This document provides brief and general guidance to WMO Members and their partner airlines on the requirements and process to develop and implement AMDAR onboard software on commercial aircraft fleets. Such development enables onboard atmospheric measurements to be accessible in near real-time for use by National Meteorological and Hydrological Services (NMHS) in numerical weather prediction and other meteorological forecasting applications for both aviation and the general public. The document consists of:

- an overview of the various aircraft and avionics (aviation electronics) platforms and AMDAR applications solutions; and
- a simple road map for the process of AMDAR onboard software development and implementation.

General descriptions and information about the AMDAR observing system and its functionality can be found on the website of WMO (see http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/).

Specific and detailed requirements for AMDAR onboard functionality are provided in the WMO AMDAR Onboard Software Functional Requirements Specification (AOSFRS), available from the AMDAR/Resources site.

Guidance on the wider requirements for implementation and operation of an AMDAR programme are available in WMO WIGOS Technical Report 2014-2, *Requirements for the Implementation and Operation of an AMDAR Programme*.

2. BACKGROUND

Until the middle of the 20th century, information and data relating to various aspects of aircraft flight operation, performance and navigation were available within the cockpit only as visual analogue or coarsely digitized displays and gauges. Then, gradually, the avionics evolved into digitized systems, either receiving digital input or converting the analogue input after reception.

In modern aircraft, atmospheric data, including static and total pressure and air temperature are sampled as close as possible to the sensor elements by the air data computer (ADC) and sent, or made available to other avionics units within the aircraft, for example, the flight management system (FMS), via digital connections.

All the flight mechanical and navigation signals as well as all other system data (for example, engine status) are processed digitally. The real-time flight data are of interest to the cockpit crew for a range of purposes associated with flight operation and aircraft performance and some elements also to air traffic management. Whereas the communication of this information in-flight was once done via voice radio, nowadays, large volumes of data can be automatically transmitted to ground via ground-based or satellite-borne networks of transceiver stations or else downloaded on arrival for use by the airline for post-flight analysis.

3. AUTOMATIC AIRCRAFT DATA PROCESSING AND COMMUNICATIONS SYSTEMS

The first international deployment of an automatic aircraft communications system is the ARINC system solution called Aircraft Communications Addressing and Reporting System (ACARS). The corresponding equipment aboard an aircraft may be called the Management Unit (MU) or, in the case of newer versions with more functionality, the Communications Management Unit (CMU). Since the late 1990s Airbus aircraft are equipped with a system called Air Traffic Services Unit (ATSU). In addition to the conventional ACARS data and message processing, this system also handles the routing of Air Traffic Control (ATC) information.

These avionics units function both as data acquisition systems and as routers for the processed data.

On some aircraft types (e.g., UPS aircraft Boeing B757) the data sampling and processing is carried out by a system called the Digital Flight Data Acquisition Unit (DFDAU), which sends these data to a separate ACARS unit. Another kind of data acquisition unit is called the Aircraft Condition Monitoring System (ACMS). These units are modular in design and transfer their output data to the system component that provides the ACARS downlink communications function.

There are a range of vendors of these avionics systems that include the most common and widespread in deployment, including Teledyne, Rockwell-Collins, Honeywell, etc.

In most cases, the unit's sampling behavior is programmable in compliance with special ARINC standards. Key standards include:

- ARINC 618 - Air/Ground Character-Oriented Protocol Specification:
  which governs the format of user defined ACARS messages (that is air to ground)

- ARINC 620 - Data Link Ground System Standard and Interface Specification (DGSS/IS):
  which describes the sampling activity and frequency being configurable depending on the user's interest.

- ARINC 429 - Digital Information Transfer System (DITS):
  which describes the data bus used on most commercial aircraft.

Using such functionality, purpose-built applications can be developed for the avionics systems to enable the controlled recording and sending of data in real-time or based on various triggers, such as time, or the value of particular parameters and variables. External and ground-based control of these applications is also possible, through the use of uplink commands sent via the communication provider to the onboard ACARS unit or the corresponding data acquisition unit. In this way, the applications can be reconfigured before or in-flight for specified sampling and reporting behavior during different flight phases.

In the case of the AMDAR onboard application - the AMDAR Onboard Software - it is the aircraft's sampled data of the ambient atmosphere that is of interest for meteorological purposes.

4. SPECIAL AMENDMENT OF ACARS FOR METEOROLOGICAL USE

4.1. AMDAR Onboard Software

In the following description, the AMDAR Onboard Software (AOS) is referred to as the "AOS module". It consists of the following components and functionality:

- ➢ Accept input data from a variety of the aircraft innate avionics equipment.
- ➢ Perform high level quality checks on the input data.
- ➢ Perform calculations upon the input data to derive required meteorological parameters
  (flags and optionally turbulence statistics).

- ➢ At set intervals, process collected data into standard output messages for transmission to ground stations.
- ➢ Accept inputs, allowing users to alter the AMDAR Onboard Software behavior.

WMO and its expert teams have historically developed and maintained several standards for AOS functionality and corresponding uplink and downlink formats:

- ➢ AOSFRS issued by WMO, an approach for overarching the standards for the aircraft communications systems:
  [see
  http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/resources/index_en.html]
  This specification provides the primary WMO meteorological-based specification for AMDAR onboard software.
  The AOSFRS defines the recommended formats for AMDAR data uplink and downlink for ACARS applications of AMDAR onboard software. This specification will be consistent with and provide the functional requirements for the ARINC 620-8 Meteorological Report Version 6.
  The AOSFRS is published and will be maintained as a CIMO, Instruments and Observing Methods (IOM) technical report.
- ➢ ARINC 620 issued by Airlines Electronic Engineering Committee (AEEC),
  i.e. for applications on ACARS units like MU or CMU (programmed i.e. by Honeywell):
  This document contains the specifications of the AMDAR onboard software, Meteorological Report (from version 1 - 6). Data link formats and flags are defined here.
  A copy of the latest specification can be purchased from the ARINC Store.
- ➢ AAA (ACARS Aircraft AMDAR) once written for applications on Teledyne units,
  These software applications have been developed by AirDatec and implemented for Qantas and Jetstar Airbus and Boeing fleets, South African Airways Airbus fleets and British Airways fleets. The AAA specification series is now superseded by the AOSFRS (see above).

The standards provide the specification of requirements for functionality and message formats for the AOS module's implementation by an avionics applications developer. It is recommended that only the most recent versions of these standards are used as a basis for new and future AOS application solutions using ACARS and alternative or succeeding systems. In particular, the AOSFRS provides the full and detailed specification of required functionality for AOS, with version 1.1 compatible and consistent with version 6 of the Meteorological Report formats as specified within the ARINC 620 Supplement 8 and later.

The feasibility of AMDAR implementation, the level of functionality and also the options (humidity, turbulence, event controlled transmissions, optional parameters for quality control) able to be implemented will heavily depend on the performance and architecture of the avionics.

Figure 1 provides a schematic and simplified overview of those parts of the avionics infrastructure playing a role in the AOS operation.

On the left hand side are the existing avionics system components that continuously generate the input for the AOS, such as

1. the air data computer for the aerodynamic parameters

2. the navigation system delivering flight mechanic data and the position

These data are transmitted to a system normally called the “flight management system” (FMS). Many of real-time flight operational processes are run in the FMS, for example, the wind calculation.

The parameters listed in the output column of the FMS box in figure 1 are transmitted to the data acquisition unit running the AMDAR on-board software (AOS). On some aircraft types this is the same unit that hosts the data link functions for ACARS (e.g. MU, CMU, ATSU, etc). On other aircraft the AOS may be run on separate data acquisition units, e.g. DFDAU or ACMS.

The parameters FMS 1. to 7. are the conventional set of AMDAR data to be processed by the AOS.

The humidity values get directly into the AOS unit via an extra ARINC 429 interface driven by the humidity sensor system.

The parameters FMS 8. and 9. are requested by the latest ARINC 620 or AOSFRS versions. These parameters are useful input to the nowcasting and the numerical weather prediction respectively.

The parameters FMS 10. to 16. are parameters being required if the AOS also consists of the turbulence statistics process.

The parameters FMS 16. to 19. are temporarily of interest for quality control purposes. The activation depends on corresponding uplink commands sent on demand to the aircraft.

Depending on the avionics architecture or the firmware’s dimensioning the AOS unit can process uplink commands from ACARS.

By all means, this unit sends the AMDAR data to ACARS for downlink transmission.
It may happen that the downlink does not only have to send the regular reports but also additional reports having been triggered in between by turbulence events.

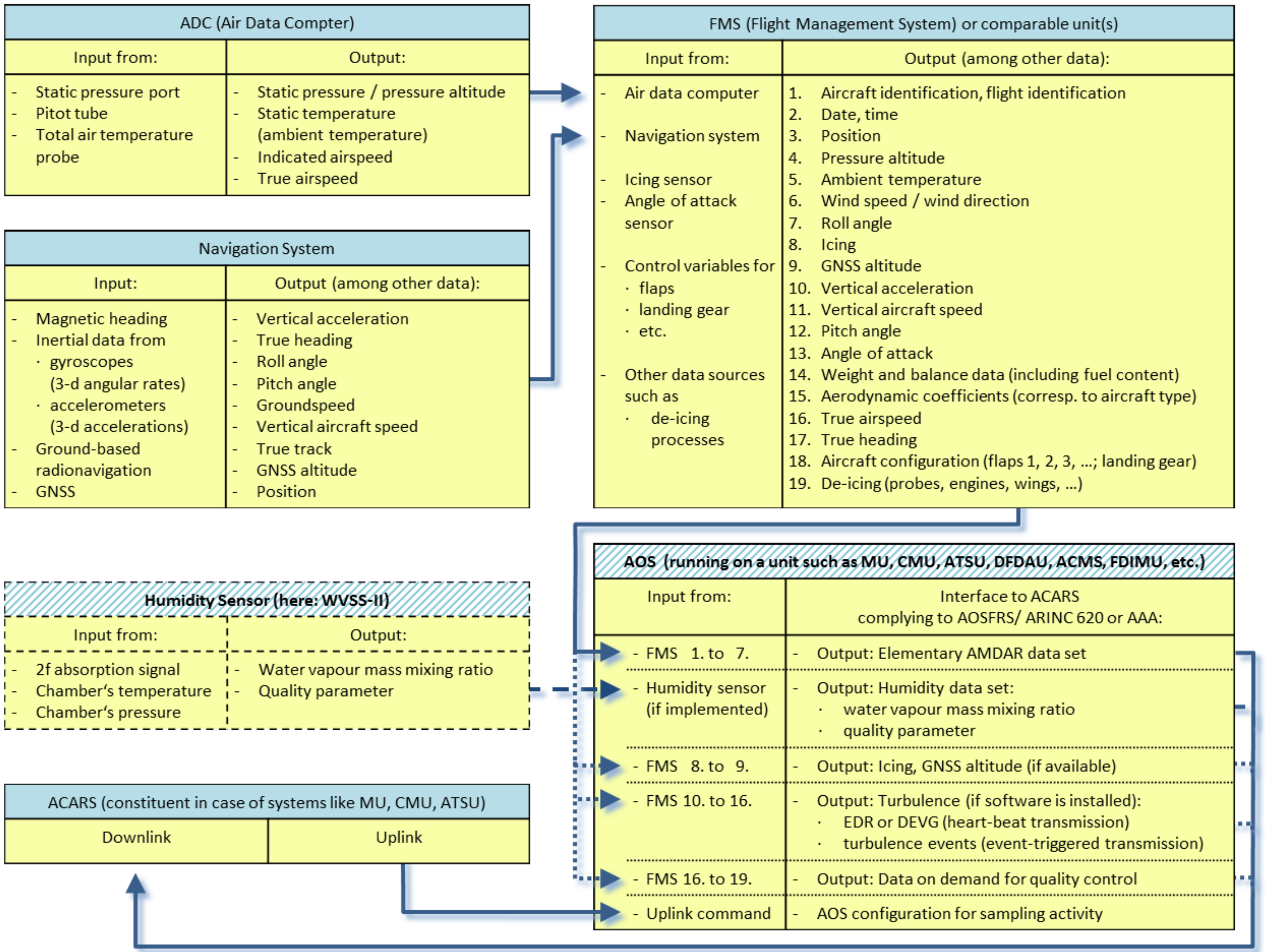

Figure 1:

Schematic overview of the information flow on an aircraft from the relevant sensors to the system component where the AMDAR On-Board Software (AOS) is running and where the transfer to the downlink process of ACARS is done.

The table blocks with the hatched title bar describe the parts which do not belong to the standard aircraft equipment.

The dashed and dotted arrows mark the handling of parameters beyond the basic AMDAR data set. Provision of humidity data depends on the existence of humidity instrumentation and on the implementation of an AOS complying with the latest AOSFRS or ARINC 620 standard.

4.2. Development and Implementation of AMDAR Onboard Software

4.2.1. Availability of Existing AOS Modules

In some cases, it may be that an AOS application is already available as an ARINC 620 compliant module (enabling provision of AMDAR reporting via the ARINC 620 Meteorological Report) within the existing avionics system and the applications suite delivered by the avionics vendor of the prospective airline AMDAR fleet.

Alternatively, it may also be possible that such an application is available but not yet installed within the particular avionics system in question. This has been true of several AMDAR programs taking advantage of Honeywell systems. However, unfortunately, at the current time, this seems to be rare and, in most cases, a special AOS application development will be necessary, especially in the case that compliance with the latest AOS standards is required.

In addition, an AOS module for the prospective AMDAR airline fleet and its particular avionics configuration may have already been developed and implemented in another AMDAR program. In which case, it may also be possible to arrange for that AOS to be provided or purchased through negotiation with either the relevant airline or avionics vendor. A list of current airframes supporting AMDAR is in Appendix 1.

However, care should be taken to ascertained if the existing AOS module provides the required functionality for the new or prospective AMDAR programme. Additionally it is often the case that an AOS module that functions correctly on one airline fleet, may not do the same on that of another, even if the avionics systems are the same, due to differences in configuration and other factors. Therefore, ground-based and in-flight testing of all AOS modules, whether new or ported from another development, should be undertaken and it should be understood that there may be a requirement for some reprogramming and/or reconfiguration of the AOS module by a developer.

4.2.2. Development of AOS Modules

The development of AOS applications for the relevant avionics equipment of an airline can be done in one of several possible ways:

- the corresponding avionics vendor;
- by a suitably qualified and certified 3rd party contractor; or possibly
- by a specialized department of the airline itself.

In most cases, the airline will make the decision about which of these possible solutions for AOS development is appropriate and/or permissible. The cost of AOS implementation is outlined in the WMO Technical Report No. 2014-02 (Requirements for the Implementation and Operation of an AMDAR Programme). Depending on the circumstances ranging from readily installable routines to the necessity of a completely new software development the costs are to be expected between US$ 10 k and US$ 100 k.

4.2.3. Process to Achieve AMDAR Onboard Software Implementation

In the Section 4 of the document, Requirements for the Implementation and Operation of an AMDAR Programme (WIGOS Technical Report No. 2014-02) the organizational project frame for the software implementation is given.

However, the required meteorological functionalities are to be programmed in compliance with or at least following the latest releases of AOSFRS and / or ARINC 620.

4.2.4. Decision about the commercial structure of the AMDAR project

The question about the topology and herewith the contract partners has to be solved. The NMHS or the regional AMDAR program has to decide if they take

- either the individual airlines
- or the network provider

as contract partner. As a consequence, the path of the downlinked meteorological data to the principal either goes

- through the airline's communication center
- or directly via the network provider.

Both cases need the cooperativeness of the envisaged airlines.

Two things have to be cleared with the airline either directly or by the contracted network provider:

- the possibility of an AOS implementation (possibly including humidity and turbulence),

and

- the legal frame of the AMDAR data use because the owner of the data is the airline.

4.2.5. The AOS design or preparation

The entity finally to be addressed for any modification of the ACARS functionality is the corresponding airline. They will decide if the communication system may be modified. Some airlines are able to do the software modification or configuration by themselves. But in most cases there is the avionics vendor or another system integration partner having the administration rights and capabilities for the avionics units hosting data acquisition and ACARS. The final success depends on several things, such as:

- performance of the AOS host unit,
- portability of possibly available software to the host unit,
- certification efforts to be financed, if an AOS could interact with system parts being relevant for aircraft security or air traffic services communication.

Depending on the feasibility and finally on the price of the implementation compared to the number of accessible aircraft with compatible AOS hosting units the NMHS or regional AMDAR program can decide about ordering.

On the side of the physical functionalities apart from the turbulence all design parts of the AOS are independent of the aircraft type. The extent of handled parameters just depends on their availability via interfaces to the AOS host unit.

The software's part for turbulence needs some coefficients depending on the aircraft type. This means some extra software configuration for each different aircraft type.

4.2.6. Testing of the AOS

The elementary precondition for this test is the correct operation of the ground systems doing both

- the separation of the meteorological data from the downlinked ACARS reports
- and the meteorological data transmission to the NMHS or regional program.

The AOS prototype implementation has to be tested during the normal flight operation over some months. The data analysis has to care about data plausibility, outliers, deviations of the meteorological parameters from the first guess background of models.

The turbulence measurement part of the AOS needs test flights for each different type of aircraft. The sampled data need to be analyzed offline by specialists who finally derive the correct coefficients to be applied for the aerodynamically different aircraft.

4.2.7. Final Implementation of the AOS

In the case of AOS without turbulence part the implementation finally just consists of identical software installations on the appropriate family of hosting units on the fleet. In case of covering also the turbulence part the installations need different modules depending on the aircraft type.

However, the realization of AMDAR software implementations always depends on the cooperativeness of the envisaged airline. They need to see the advantages of the outcome on the side of the weather forecasts as well as on the side of a better quality control over the onboard instruments.

4.3. Ground Component of AMDAR Software

While not strictly part of the AMDAR Onboard Software, any development needs to consider the ground software systems that have the job of converting AMDAR data and controlling the AOS activity. Currently there is no international standard for this, with many different implementations in use around the world.

Two main considerations are:-

- Conversion/decoding of downlinked data
- Optimisation of AMDAR data collection

4.3.1. Converter for Downlinked Data

The meteorological data sent to the ground have to be picked out of the ACARS downlink data stream and sent to the corresponding NMHS or the data management centre of the regional AMDAR program. This diverting job can either been done by

- the contracted airline as being the proper receiver of the data or
- (by agreement with the airline directly) the broadcasting network service provider such as ARINC or SITA, or
- by the receiving NMHS

In any of these scenarios it is necessary to implement or at least configure software systems for that data diverting job.

4.3.2. Ground-based Optimisation & AOS Control

Ideally, the AOS should be controllable via ACARS uplinks as this can provide a significant operating cost reduction by limiting redundant data. For example, within a region like central Europe there are a large number of AMDAR configured aircraft. Over the frequented air traffic hubs the problem of costly redundancies by too many ascend and descend profiles has to be solved. Via an optimizing tool driven on a ground based system the meteorological ACARS use can be activated or deactivated in a way that the frequency of profiles gets just as required in time and space. The user gets a sampling activation on flight segments selected by an optimization process.

The AOS features to be switchable should be

- activity of data downlinking during previously selected flight phases,
- adding of flight operational parameters for quality control purposes.

The detailed requirements for the uplinks are given by ARINC 620 and AOSFRS. An overview about the already existing systems for optimization and AOS control is given in << PROPOSAL FOR GUIDANCE ON AMDAR OPTIMISATION >>.

ANNEX I: LIST OF AMDAR VERSIONS AND PLATFORMS

Airframe	Subtype	AMDAR Format[10]	AMDAR Program	ACARS System[11]	Data Acquisition System[12]
A300			USA		
A310			USA		
A318		AAA v3	E-AMDAR		
A319		A620-3 v2	E-AMDAR		
		A620 v2	E-AMDAR		
	100	AAA v3	South Africa		
			USA		
		AFIRS	Australia		
A320	200	AAA v3	Australia		
		A620-3 v2	E-AMDAR		
		A620 v2	E-AMDAR		
	200	NZ Proprietary	New Zealand		
		A620-6	South Korea		
	200	AAA v3	South Africa		
			USA		
A321		AAA v3	Australia		
		A620-3 v2	E-AMDAR		
		A620 v2	E-AMDAR		
A330		A620-3 v2	E-AMDAR		
		A620 v2	E-AMDAR		
	200	AAA v3	South Africa		
			USA		
A340		A620-3 v2	E-AMDAR		
		A620 v2	E-AMDAR		
	300, 600	AAA v3	South Africa		
A380		A620-3 v2	E-AMDAR		
B717		A620 v2	E-AMDAR		
B727			USA		
B737	800	AAA v3	Australia, E-AMDAR		
	800	ADCC	China		
		AAA v2	E-AMDAR		
		A620-3 v2	E-AMDAR		
	300	NZ Proprietary	New Zealand		
		A620-6	South Korea		
			USA		

[10] AAA: ACARS Aircraft AMDAR (version 1, 2 and 3 in use) see http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/resources/index_en.html
A620-x: AEEC 620-7 Data Link Ground System Standard and Interface Specification (DGSS/IS). see http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/resources/index_en.html
ADCC: Aviation Data Communication Company

[11] Options include: ACMS,

[12] Options include: ACMS, ATSU,CMU,DFDAU,DMU, FDMU

Airframe	Subtype	AMDAR Format[10]	AMDAR Program	ACARS System[11]	Data Acquisition System[12]
B747	400	AAA v1	Australia		
		AAA v2	E-AMDAR		
		A620-3 v2	E-AMDAR		
	400	A620-3 v2	Hong Kong		
		ACMS	Japan		
	400	A620-6	South Korea		
B757			USA		
B767	300	AAA v1	Australia		
		AAA v2	E-AMDAR		
		ACMS	Japan		
			USA		
B777	200 300 300ER	ACMS	Japan		
			USA		
B787		ACMS	Japan		
CRJ	200, 200ER	ARINC 620-4	Canada		
		A620-3 v2	E-AMDAR		
DC8			USA		
DC9			USA		
DC10			USA		
MD10			USA		
MD11		A620-3 v2	E-AMDAR		
		AAA v1	E-AMDAR		
			USA		
MD82			USA		
MD83			USA		
MD88			USA		
MD90			USA		

ANNEX V

World Meteorological Organisation

Guidance on AMDAR Observing System Data Optimisation

Commission for Basic Systems
Expert Team on Aircraft Based Observing Systems

Version 1.0, December 2014

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BACKGROUND

AMDAR

Aircraft Meteorological DAta Relay[13] predominantly uses the on-board aircraft sensors to measure meteorological information. The resulting data are then transmitted to the ground via VHF or satellite link using the aircraft's own communications system (ACARS - Aircraft Communications Addressing and Reporting System). When the airline receives the data, it sends it on to the National Meteorological and Hydrological Services (NMHS) where it is processed, checked for quality and incorporated into meteorological applications, including Numerical Weather Prediction (NWP) models and forecasts for aviation.[14]

The WMO global AMDAR system now produces over 600,000 high-quality observations per day of air temperature, wind speed and direction, together with the required positional and temporal information and with an increasing number of humidity and turbulence measurements being made.

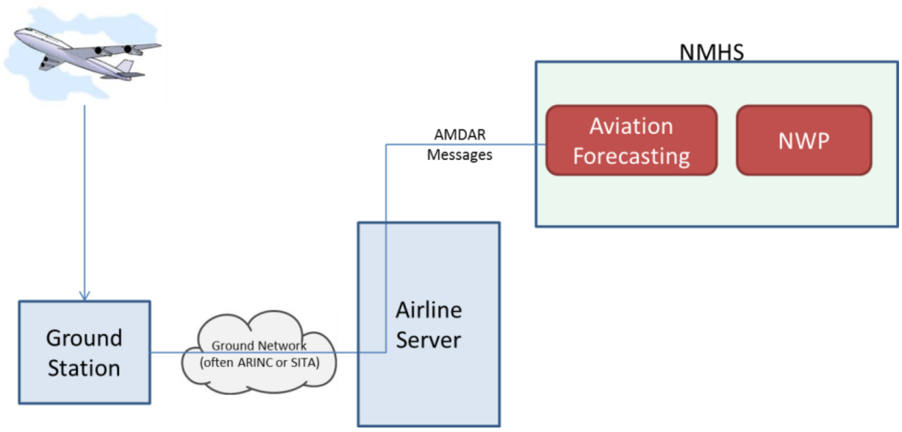

Figure 1: Block diagram of a typical non-optimised AMDAR Observation System

While the cost per observation is generally lower than for other upper air measurement systems, for example, the balloon borne radiosonde measurement system, most AMDAR programs involve a cost for each observation received by the NMHS. A large component of this cost is associated with the air to ground communications which, particularly over remote land and ocean areas, can be significant in a larger program with a fleet of many aircraft. It becomes a more significant issue still when satellite communications are required to be used (in preference to VHF communications).

REQUIREMENTS FOR DATA

Redundant Data

Redundant data are any observations that are surplus to requirements of data users and their applications. Meteorological requirements for upper air observational data are defined by WMO under its Rolling Review of Requirements[15] process. WMO Members should ensure that they are

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[13] See http://www.wmo.int/amdar for more information.

[14] The WMO AMDAR Observing System: Benefits to airlines and aviation. http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/documents/JN14991_amdar_foldout_080914_en.pdf

[15] See: http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html

aware of both national and international requirements of data users for the provision of upper air data before determining the best methods and configurations for optimisation of aircraft-based observations and AMDAR observing systems.

Importantly, some data users may actually specify a requirement for what might initially be considered "redundant" data. For example, numerical weather prediction systems may be advantaged by the provision of one or more additional observations of particular variables at the same point in space and time so as to obtain or allocate a higher degree of certainty to such observations. Consideration of such requirements should also be made.

Data Coverage

Data coverage refers to the spatial and temporal distribution of aircraft observations.

For an AMDAR Program with redundant data, there are two key aspects of data coverage that are required to be specified and controlled:

1. The temporal and spatial separation of vertical profiles (of meteorological parameters) made on aircraft ascent and descent; and,
2. The temporal and spatial separation of isolated reports made during level flight.

The principal aim of an effective AMDAR data optimisation system is to enable delivery of output data at sufficient spatial resolution and temporal frequency to satisfy user requirements, without delivering greater volumes than required (redundant data).

One of the challenges is that such requirements may vary with location, local weather situation and season.

Whereas data supply will depend on:-

- passenger demand : this affects the number of aircraft that fly to a destination, and the types of aircraft used;
- Airline priorities and agreements made with NMHS for provision of data; and
- Airport capacity and regulations (for example curfews)

Figure 2 shows modelling based on data from the Australian Bureau of Meteorology. While actual figures for each AMDAR program will vary, the relationship between AMDAR fleet size and the trends in vertical profile production and redundancy are likely to be similar:

- The % of redundant profiles increases linearly with the number of non-optimised aircraft. In this data, with 50 aircraft ~1/3 of the profile are redundant.
- The number of redundant profiles (and hence their cost) increases non-linearly with the number of non-optimised aircraft. That is, a greater percentage of, a greater number of profiles are redundant. In this particular example, the number of redundant profiles increases as the square of the number of aircraft.
  Based on this program and the requirements specified, 50 aircraft produce ~66,000 redundant profiles a year. Assuming US$2/profile, this amounts would amount to $132,000/year in redundant data and a potential saving of 33percent of communications costs if eliminated

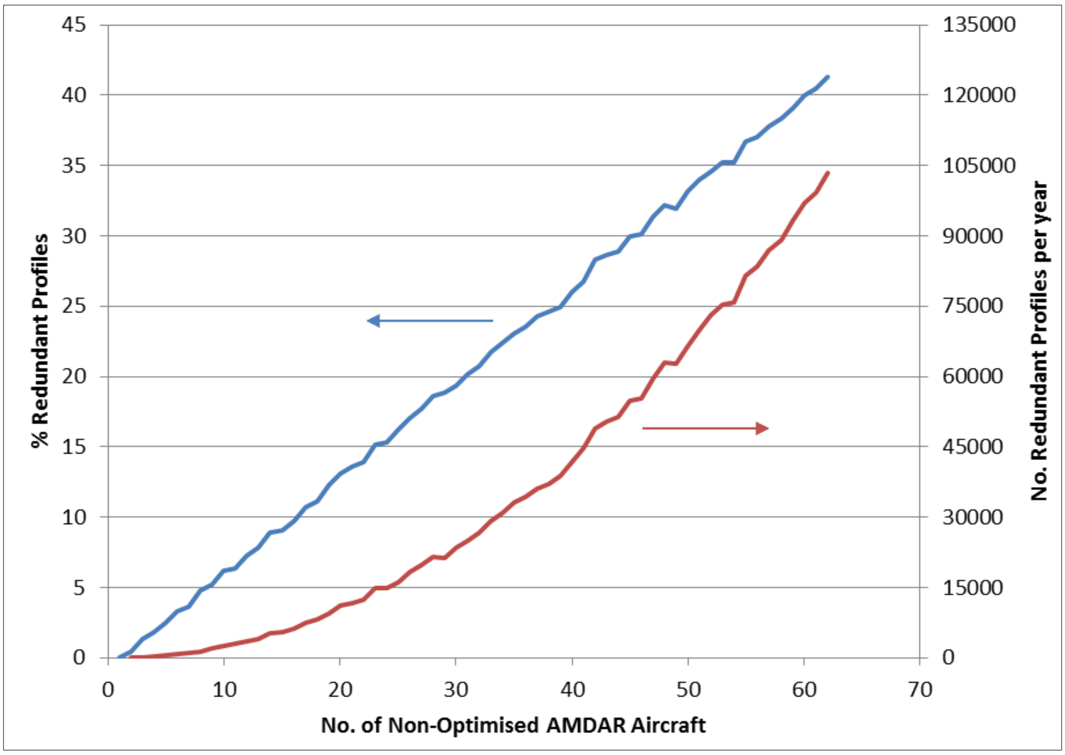

Figure 2: Increase in Redundant Data with number of aircraft

OPTIMIZATION METHODS/STRATEGIES

AMDAR Software Capabilities

The AMDAR On-board Software Functional Requirements Specification (AOSFRS) specifies possible functionality of the AMDAR onboard software which would allow for varying degrees of data optimisation, depending on the level of compliance implemented. This includes:-

1. Initiation of AMDAR onboard software configurations to manage:-
   - Production of vertical profile data at a list of airports
     - with airport specific profile frequencies
     - with airport specific sampling frequencies
   - Production of AMDAR data during the enroute phases with aircraft specific sampling frequencies
   - Production of AMDAR data within geographical boxes.
   - Production of AMDAR data within time windows.
2. Ability to adjust stored configurations both manually and remotely.
3. Ability to receive and process requests to remotely make changes to the AMDAR reporting configuration, to be effective either permanently or for the current or next flight only.

While use of the stored/default configurations for each aircraft can provide a degree of control over data output and program optimisation, in isolation, it is (by definition) unable to respond dynamically to the reporting of observations by other aircraft, which will be variable and changing, being subject to airline operational schedules. For this reason, the ability to make changes to an aircraft configuration, both remotely and automatically, in response to a command request, is required.

Remote changes typically require a formatted command message to be sent to the aircraft using the standard ACARS (data) link. This command is often referred to as an *uplink*.

AMDAR Optimisation Systems

While it is feasible for some degree of data optimisation to be achieved by a person issuing uplink commands in response to changing conditions, the best solution comes from using a ground-based and automated (optimisation) system. This allows 24/7 response to changing meteorological requirements for data and aircraft operations and data availability.

The section below outlines the steps such optimisation software ideally should implement. The perfect system would be one that had the flexibility to manage all the AMDAR equipped aircraft available to a NMHS. This allows the best response to changes in weather conditions and demand.

However, it is recognised that in practice, perhaps due to issues of compatibility between the systems used by different airlines or due to their preferences, an AMDAR optimisation system may well have to rely on individual airline-by-airline optimisation.

Optimisation System Processes

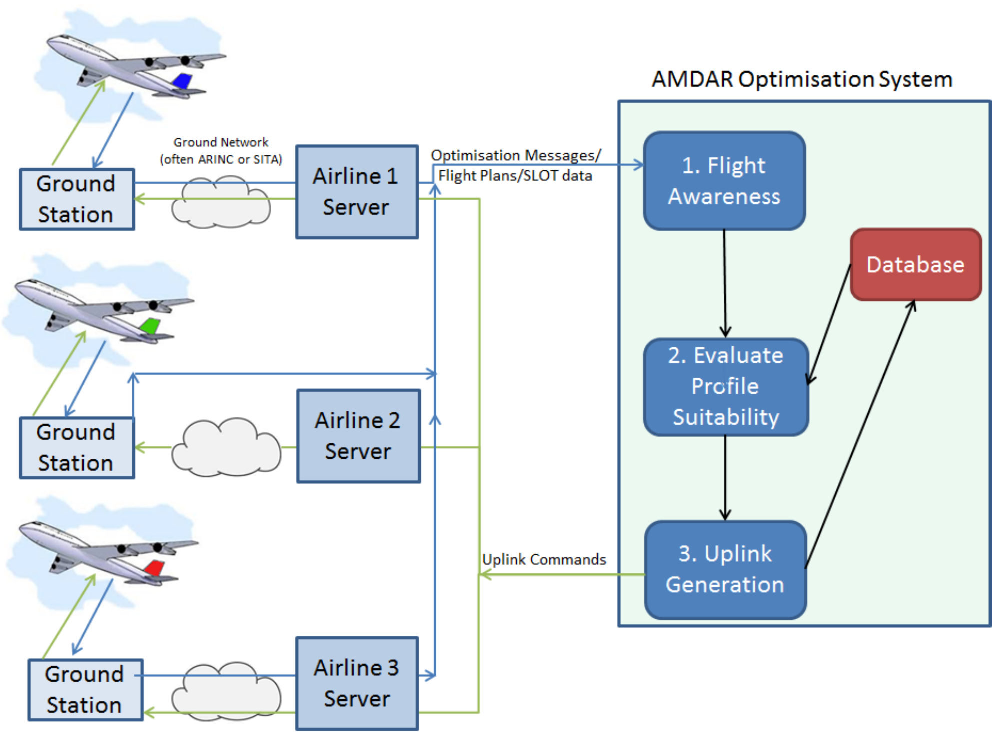

Figure 3: Block diagram of a full AMDAR optimisation system.

A full AMDAR optimisation system is depicted in Figure 4 and consists of three main steps. These are outlined in greater detail below, but consist of:-

1. Flight Awareness: Before take-off (generally when the aircraft leaves the gate) it sends an Optimisation Message to the AMDAR Optimisation system. This contains sufficient

information for the System to identify the aircraft and the route (origin/destination) involved. Alternatively, the aircraft can be identified from flight plans.

2. Evaluate Profile Suitability: Before the aircraft takes off, the Optimisation system decides what data, if any, is required from this flight and
3. Uplink Generation: sends the appropriate uplink command to switch on/off data collection during the different flight phases. Even if no data is required from this flight, an uplink command may still be required to override the settings from the previous flight by this aircraft.

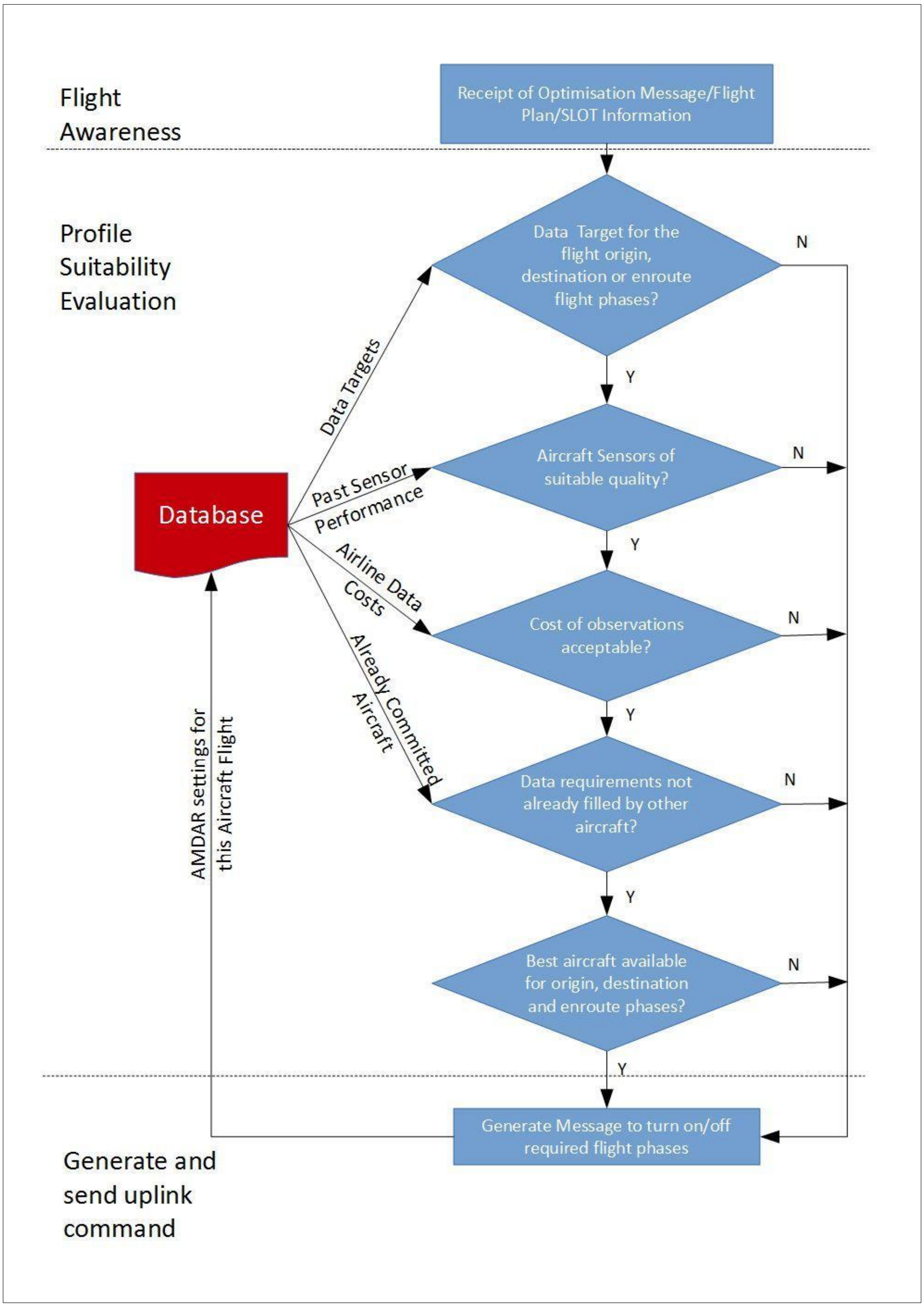
Flight Awareness
Receipt of Optimisation Message/Flight Plan/SLOT Information
Profile Suitability Evaluation
Data Target for the flight origin, destination or enroute flight phases?
N
Y
Data Targets
Aircraft Sensors of suitable quality?
N
Y
Past Sensor Performance
Database
Airline Data Costs
Cost of observations acceptable?
N
Y
Already Committed Aircraft
Data requirements not already filled by other aircraft?
N
Y
Best aircraft available for origin, destination and enroute phases?
N
Y
AMDAR settings for this Aircraft Flight
Generate Message to turn on/off required flight phases
Generate and send uplink command

Figure 4: Decision Steps for AMDAR Optmisation processing.

Step 1: Flight Awareness

The first stage of any optimisation is the system "becoming aware" of an AMDAR aircraft flight. This can be the result of the receipt of an Optimisation Message. Alternatively, flight plans can be reviewed to extract the required information.

Whatever the format, the message contains (at a minimum):-

- Aircraft identity – either providing or able to be linked to the aircraft call sign (or tail number)
- Flight origin
- Flight destination
- Time of departure
- Time of arrival at destination

Step 2: Profile Suitability Evaluation

Once the optimization system is aware of a flight, it must decide if that aircraft meets the requirements or if there is a better flight available. In any case the optimization system must decide which flight phases (if any) shall be configured to report AMDAR data.

The decision to activate or deactivate the AMDAR onboard software for data collection will depend on one or more of the following factors:-

- Data Requirements:-
    - From the "Flight Awareness" phase, the flight origin and destination are known. Thus it can be determined where and (an estimate of) when profiles (on aircraft ascent and descent) and the series of enroute reports (made between the departure and destination airports) will be generated.
    - This potential data availability is then compared to a maintained set or database of rules or targets for AMDAR data collection for a list of airports, areas and routes, which are based on the requirements for upper air data. Rules may also be dependent on:-
        - time of day
        - season
        - local weather conditions
        - a preference for ascent profile data over descent
        - a special area or airport configuration
        - a preference for short or long-haul flights
        - a preference for en-route reporting

- Aircraft reporting and configuration status:-
    - From the "Flight Awareness" phase the identity of the aircraft is known. This can be used to interrogate an internal NMHS database to determine the status of the aircraft based on available metadata. Factors to be considered include:-
        - Data quality of reported parameters: Has the aircraft been "black-listed" for reporting based on previous data quality checks, e.g. comparison to computer model or radiosonde.
        - The preference of one aircraft over another for the provision of critical parameters, e.g. the reporting of humidity or turbulence.

- Aircraft/Airline observation cost:-
    - From the "Flight Awareness" phase the identity of the aircraft is known which can then be used to obtain from the database the aircraft or airline-based cost of the data.
    - This can be compared with the costs of any alternative flights for the same time and departure or destination airport and the enroute segment.

- Flights already committed by aircraft not configurable by uplink:-
  - There may already be aircraft committed to provide some or all of the data requirements for the particular time and flight phases offered by the uplink-capable aircraft. While these may not be changed by the optimisation system, they might be taken into consideration if the system is "aware" of their operations.
  - An optimisation system can be made aware of these flights and their output data from their OOOI/Optimisation messages, or deduced from received observations, if these messages and data are provided to and processed by the optimisation system.

- Uplink capable AMDAR aircraft already committed:-
  - Many airlines charge a cost for uplink messages. The comparative cost of uplink vs downlink/observation messages determines whether changing an aircraft configuration in flight provides any benefit.

No data may be required from this flight because the AMDAR quota for the origin and destination airports, and the route are already filled by flights nearby in time and/or space.

An optimisation system may wait to see if "better" aircraft becomes available (for example one with a humidity sensor). While changing an aircraft's configuration during flight is usually possible, the decision on, at least, whether an Ascent Profile is collected needs to be made before the aircraft takes off.

Step 3: Generate and Send Uplink Command

Once the optimisation system has decided which flight phases (if any) to activate, the system should generate the necessary message(s) and send it (them) automatically.

An uplink message may still be required to turn off flight phases that are activated from previous flights or by default.

Uplink Message Security

Airlines understandably have security concerns about allowing third parties to directly uplink to their aircraft. Instead, the optimisation system may send uplink commands to an airline server, where they undergo further checks before being sent to the aircraft. These checks are ideally automated (to save time and allow continuous, unattended operation), but may require additional interfaces to be developed on the airline server.

Airline server checks include:-

- Message formatting is correct – parameters are within allowed ranges and there has been no corruption during transmission.
- Message type/content is allowed – only certain types/formats of uplink messages are authorised to be sent by the optimisation system. This stops a hacked optimisation system having unlimited access to the aircraft.
- Message volumes are within acceptable limits. This stops a malfunctioning (or hacked) optimisation system overloading the aircraft uplink.

Optimisation System Formats

Flight Awareness Messages

Several formats are currently in use including:-

- OUT[[16]] message

[16] [OUT of the gate, OFF the ground, ON the ground, INTO the gate, collectively known as] OOOI messages are transmitted automatically by aircraft systems to the ground station. These are used by the airline industry to track the status of aircraft.

- G-ADOS[17] OPS or SLOT format
- AOSFRS[18] Optimization Message.

Uplink Messages

Currently a number of different formats for this message are in use. The key difference between the formats is whether the message is:-

- passed unchanged through the airline servers to aircraft [BOM ADOS, AOFSRS]
- in a format that an airline's server translates into the appropriate (airline specific) format [G-ADOS]

AMDAR OPTIMISATION SYSTEM FUNCTIONALITY REQUIREMENTS

Component	Functionality	Section	Importance
System User Interface	Allow modification of targets for data coverage		Essential
System User Interface	Allow NMHS direct access via a graphical user interface.		Recommended
System User Interface	Allow temporary adjustment of coverage targets for a set period, followed by reversion to a default.		Optional
System User Interface	Allow maintenance of fleet metadata		Essential
System User Interface	Allow configuration for:- - airports - aircraft - geographic areas		Essential
Database	Store target number of profiles for an airport (e.g. profiles per hour).	1.2.3.2	Essential
Database	Store target data coverage for routes (i.e. airport pair), e.g. route legs per hour.	1.2.3.2	Recommended
Optimiser	Awareness of future flights with enough lead time to make decisions as to best aircraft configurations to meet targets	1.2.3.3	Essential
Optimiser	Algorithm to decide which phases of flight (if any) to enable	1.2.3.3	Essential
Optimiser	Optimisation incorporates preferential selection of aircraft based on measurement capabilities		Recommended

17 G-ADOS General Task Description, v1.8 29th October 2014, Deutscher WetterDienst

18 AMDAR Onboard Software Requirements Specification (AOSFRS). Latest version is available at the WMO AMDAR/Resources site: http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/resources/index_en.html#amdar_stds

Component	Functionality	Section	Importance
Optimiser	Optimisation incorporates preferential selection of aircraft based on observations cost		Optional
Optimiser	Optimisation incorporates preferential selection of aircraft based on measurement quality status		Recommended
Optimiser	Optimisation incorporates preferential selection of aircraft based on estimated time of flight phase		Optional
Optimiser	Reception and analysis of response and non-response to uplink commands		Optional
Optimiser	Reception and analysis of AMDAR data to assess response and non-response to configuration and measure of		Optional
Database	Ability to store current aircraft configurations for reference when assessing future flights	1.2.3.3	Essential
Communications	Ability to send (re)configuration messages to aircraft (possibly via airline server)	1.2.3.4	Essential
Database	Store data quality status information for aircraft to assist configuration decisions	1.2.3.2	Recommended
Database	Store aircraft additional sensor (eg. Water Vapour, icing) to assist configuration decisions	1.2.3.2	Recommended
Database	Store airline/aircraft data cost to assist configuration decisions	1.2.3.2	Optional

APPENDIX A: AMDAR OPTIMISATION IMPLEMENTATIONS

A.1 Australian Bureau of Meteorology

The Australian Bureau of Meteorology runs a fully automated AMDAR Optimisation System (ADOS). The screenshot (Figure 4) shows the available options for each aircraft, including:-

- o Sensor quality information for Temperature, Wind, DEVG (Turbulence) and Water Vapour
- o Aircraft specific rules for
- o Airport
- o Latitude/Longitude Reporting boxes
- o Reporting times.

This system uses the OOOI messages as its Flight Awareness message and generates an uplink command that is passed unchanged to the aircraft after checking by the airline's servers.

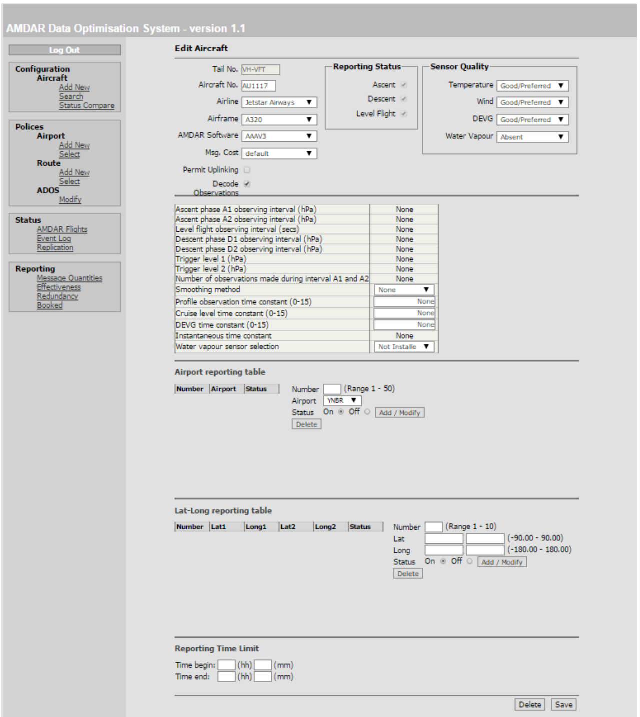

Figure 4: Australian Bureau of Meteorology ADOS system screen shot.

A.2 E-AMDAR

Currently, the E-AMDAR program has a range of optimisation options. These include :-

- E-AMDAR Data Optimisation System (E-ADOS):
  - o Full automated and flexible AMDAR optimization
  - o Graphical interface allows real configuration
  - o Optimisation configurations for airports, aircraft, routes and geographic regions in general or for time periods
  - o For Flight Awareness E-ADOS accepts several message formats including IATA (ASM and OOOI) messages.
  - o Standard format Flight Awareness and Uplink Command messages are generated by the system, which each airline then translates/adapts to their own system.

Alternatively an uplink command is generated that is passed unchanged to the aircraft after checking by the airline's servers.
- Supports uplink message formats according ARINC-620 and AAA V3 specification.
- Airlines:
    - Lufthansa
    - Cityline
    - German Cargo
    - Germanwings
    - Thomas Cook Scandinavia
    - Finnair
    - Austrian Airlines
    - KLM (B737NG Fleet)

- AFR Flight Selection System (FSS):
    - Optimisation on profiles in a time period (eg 1 profile in 120 minutes) at an airport
    - Aircraft:
        - Air France A320 Fleet

- SAS Flight Selection System:
    - Optimisation on city pairs (that is, can select ascent, cruise or descent profiles for a route eg. LGKF to ENGM
    - Airlines:
        - Scandinavian Airlines (SAS)
        - Blue1 (BLF)
        - Novair (NVR)

- British Airways Flight Selection System:
    - Optimisation rules for each participating airport
    - Aircraft:
        - British Airways B737, B747, B767 fleets

- EZY ARINC OpCenter:
    - Optimisation on airport/route pairs
    - Airline:
        - easyJet