WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS
OPEN PROGRAMME AREA GROUP
ON INTEGRATED OBSERVING SYSTEMS

EXPERT TEAM ON AIRCRAFT-BASED OBSERVING SYSTEMS
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Guidelines for AMDAR Program Development

(*Submitted by Frank Grooters)*

SUMMARY AND PURPOSE OF DOCUMENT

Guidelines and budgetary estimates for the development of a national or regional AMDAR program are needed for inclusion in the relevant ABO related WMO guide(s). The AMDAR Panel had produced a preliminary document for presentation to potential AMDAR partners. This document could be used as a basis for an updated document providing guidelines for AMDAR Program Development under the ABOP.

ACTION PROPOSED

The meeting will be invited to note the initial AMDAR panel document reflecting guidelines and relevant information for the development of a national or regional AMDAR program.
The meeting will further be invited to discuss a way forward leading to an updated document providing guidelines and budgetary estimates for the development of a national or regional AMDAR program.

References

1. ET-ABO Work Plan 2013-2014

DISCUSSION

1. The ET-ABO Work Plan provides for the development of Guidelines for AMDAR Program Development to be implemented in the relevant WMO WIGOS/GOS regulatory material.

2. This guide should support potential national and regional AMDAR Program Managers when developing a new AMDAR program.

3 The first AMDAR Technical Coordinator, Mr Jeff Stickland, had developed preliminary guidelines, including relevant budgetary estimates, and being used by the AMDAR Panel in its support to the possible establishment of new AMDAR programs (**Appendix**);

4. These AMDAR Panel Guidelines for AMDAR Development could be reviewed and updated by the ET-ABO, with the aim to produce a first draft of Guidelines for AMDAR Program Development, as one of the results of the first meeting of the Expert Team;

5. The meeting is invited to find a way and time during the meeting to review the AMDAR Panel document and to produce a first draft for the ET-ABO Guidelines for AMDAR Program Development.

APPENDIX

AMDAR DEVELOPMENT AND COSTS

(2002, Jeff Stickland, AMDAR Panel Technical Coordinator)

Introduction

1. A number of critical steps and decisions are needed by a national meteorological service (NMS) if it wishes to proceed with the development of an AMDAR program. This paper outlines briefly the major components and decisions needed.

Major Building Blocks

2. An operational AMDAR system requires several major components for the production, communication and use of automated reporting of meteorological observations of temperature and wind. Each component will be described in more detail below:

- A national airline willing to participate in a cooperative partnership with the NMS;

- The airline must have aircraft equipped with an appropriate communications system and avionics hardware to run one of the freely available AMDAR software packages. AMDAR takes advantage of existing operational infrastructure on modern aircraft such as high quality navigation systems, meteorological sensors and automated communications systems. Only special software is required to be installed and run in the avionics systems. This software accesses information from the aircraft data bus and prepares specially encoded messages for transmission to either the airline, or in some cases direct to the NMS via one of the global communications providers for the aviation industry;

- A means for the NMS to receive data either directly from the aviation communications provider or the airline. This is done using one of a variety of ground-based communications providers through a direct link;

- A ground-based processing system operated by the NMS that receives the data via landline from either the airline or communications provider. This system recognises the formatted data, conducts basic message format and quality checks, re-encodes the data to a suitable format then distributes them for national operational use and exchange over the GTS;

- A system for monitoring data quality. There are several ways in which this can be done at the national level to the detailed standard required to support an operational system. Also, some NMSs conduct monitoring on behalf of other NMSs based on a regional cooperative agreement. The global monitoring centres also provide monitoring services, but these are not normally detailed enough to provide an adequate level of support at the operational level;

- A data optimisation system that provides real-time control of the production of observations to minimise redundant data while still providing the required standard of national (and perhaps international) coverage. The aim is to optimise the cost benefit of the observing system. This item is not normally necessary in the early stages of a developing program mainly because the question of data redundancy does not arise until it has become reasonably mature with many reporting aircraft. It is technically feasible for this part of the program to be provided by another region. The EUMETNET-AMDAR program is offering to coordinate and run a global optimisation system for all airlines wishing to become involved.

System Description

Airlines

3. Most countries have a number of airlines. Typically, these consist of national and international carriers, regional airlines that operate only within given parts of the country and the smaller general aviation airlines. Experience shows that only the large national and regional airlines are interested in participating in AMDAR programs because they can afford the expensive avionics hardware and communications infrastructure installed for their own operational purposes. By participating in a cooperative AMDAR program with the NMS, the airlines see direct benefits returning to them through improved aviation meteorological services. In turn, these improved services are used to provide better passenger (or freight) services through operational efficiencies, aircraft performance and safety. It is extremely difficult to place a monetary value on this, but airlines understand the cost savings derived from better performance and passenger satisfaction of shorter and safer flights, and flights arriving on time.

Improved NMS Aviation Weather Services

4. The task for the NMS is to convince the airline that AMDAR observations will improve forecasts and warnings for the airline in return for its cooperation in providing data. This message is normally conveyed through several meetings/briefings and perhaps by the preparation of a business case. It should also be explained to the airline that a small amount of AMDAR data in their region is already being provided to the NMS and the two ICAO World Area Forecast Centres. The data is being produced by visiting aircraft from other countries as part of the contribution to the WMO World Weather Watch Programme by the NMS of those countries. By participating in a national AMDAR program and perhaps in a long haul international program later on, the airline will be joining participating airlines from other countries in a coordinated global AMDAR program of mutual benefit to all airlines and NMSs.

Appropriately Equipped Aircraft

5. It is essential to determine quite early in the approach to the airlines whether they have appropriately equipped aircraft to operate an AMDAR system. There are many reasonably modern aircraft operating globally that are not so-equipped and therefore unable to run AMDAR. Providing the infrastructure is the responsibility of the airlines and the communications providers. If an airline does not own equipped aircraft, there is little an NMS can do about it other than to encourage the airline to consider upgrading existing fleets or replacing them with new aircraft. Some will be interested in doing this, but many will not.

6. The basic essential items include:

- Appropriate onboard data, meteorological sensors and accurately derived observations including date and time, pressure altitude, position (latitude and longitude), static air temperature, wind speed and direction and aircraft roll angle used to determine data quality. For more sophisticated observations such as turbulence, departure from the aircraft reference normal acceleration (usually close to

1.0), aircraft mass, mach number, attitude (roll, pitch and yaw), automatic pilot flag, and gust alleviation control settings. Development of water vapour measurements is underway in the US and the UK. It is anticipated that a reliable operational system will not be ready for several more years;

- Avionics hardware able to run one of the free AMDAR software packages. Several avionics manufactures provide this hardware (Teledyne, Honeywell, Allied Signal (now part of Honeywell), SAGEM-SFIM and Universal Avionics on aircraft from Boeing, Airbus, MacDonnell Douglas, Hawker De-Havilland, etc).

- The communications infrastructure is normally provided by one of the 2 large provider companies (ARINC and SITA) for the global aviation industry (although a new operational system has recently been developed based on the low earth orbiting satellite system that one regional airline in Canada is using to develop an AMDAR system). Independent communications companies are operating similar aviation services in Japan, China, Thailand and Brazil that link to the global services provided by ARINC and SITA. The communications system is called Aircraft Communications and Reporting System (ACARS). Airlines contract with one or more of these companies to provide global communications services for their own commercial operational purposes. Both companies provide 2-way communications based on VHF, HF and satellite systems. VHF is the cheapest system followed by HF then satellite. The airline(s) hopefully will already have these services. This is basically an issue for the airline, but the main point for AMDAR is that the cost of transmitting data will vary significantly according to the system used.

- AMDAR software is normally available free of charge, however some airlines may charge to make customised modifications and installation. The two main sources of software are:

\- The Royal Netherlands Meteorological Service (KNMI) in conjunction with the airline KLM. The software package called Aircraft ACARS AMDAR (AAA) is free but is suitable only for aircraft fitted with Teledyne avionics management systems called Aircraft Conditioning and Management System (ACMS) and an appropriate ACARS communications system. The software provides significant operational flexibility and is currently being upgraded by KLM according to a EUMETNET-AMDAR specification to include additional functionality. A private company of very experienced avionics engineers from KLM who are experts in AMDAR software has been established to provide technical advice to prepare and install the software via fax, mail, e-mail, telephone for a small one-off charge of several hundred US dollars. They will also provide additional assistance if required by travelling to the country and working alongside airline engineers at cost to the airline. This software is used operationally by airlines KLM, SAS, BA, SAA and Air Namibia. Saudia is also preparing to install the software.

\- Avionics hardware suppliers Honeywell (Allied Signal), Teledyne, Rockwell Collins, SAGEM/SFIM and Universal Avionics. The software is developed to the aviation industry standard specification ARINC 620. This AMDAR software is written as a module for certain makes and models of avionics hardware and is normally free of charge as an additional option. The performance standards and functionality vary considerable between suppliers. The airline must specifically request this module be provided by the avionics company. The airline will then need to integrate the AMDAR software into the complete avionics package by recompiling it. It may be necessary for the airline to modify optional settings to suit the requirements of the NMS. In some cases, AMDAR software can be incorporated into the ACARS communications management system.

- A means of communicating the data to the NMS is required. Most airlines insist that all data must first be sent directly from the aircraft to their ground based data systems. Some airlines then on-forward the data without change to the NMS. Other airlines reformat the data to a form suitable for the NMS. In yet another variation, the NMS has its own ARINC/SITA address and the data are forwarded directly without first being sent through the airline. The airlines do receive a drop copy of the data but do not use it. The direct landline circuit used can be provided by any commercial provider.

- A data acquisition system normally located in the NMS is required to receive the data, check format and message consistency, conduct rudimentary data quality checks (range, rates of change, observations consistency etc), reformat the data into acceptable messages/bulletins for operational use within the NMS and for exchange on the WMO GTS. WMO message formats include FM42 AMDAR and FM94 BUFR. It may be necessary to be able to recognise a range of different incoming message formats because more than one airline may be used, each producing its own message format. An essential function of this system is the ability to withhold distribution and exchange of data selectable on an individual aircraft basis when data quality is known to be unacceptable. The system can continue to monitor the poor performing aircraft until such time as the data are once again acceptable, whereupon the data can once again be distributed.

It is the responsibility of the NMS to ensure this system is developed and operational by the time the airlines commence producing data. A system developed for the UK Met Office is available commercially and the provider is willing to adapt and install the system in any country to the country's operational specification. On the other hand, many NMSs develop their own message recognition and data processing systems in house.

In the situation where several neighbouring countries are operating national AMDAR programs, it is suggested that a cooperative regional approach be taken with the data processing system in order to avoid duplication of effort and resources. This approach requires the development of only one system which then collects data for all countries in the region.

- The development of a single non-real time data quality monitoring system on a regional basis is also strongly encouraged. It has been found through experience, that the information and reporting frequency provided by the global monitoring centres is insufficient to support an operational system on a day-to-day basis.

  Three different methods are used operationally by various countries/regions:
  - Intercomparison with numerical model first guess fields;
  - Intercomparison with radiosonde soundings;
  - Intercomparison with other AMDAR aircraft.

- The development of a fast, real-time data quality control system by the NMS is also highly desirable to prevent erroneous data being exchanged. This is a difficult task and one that most countries are still addressing. The concern is that such a system could delay the distribution of data to such an extent that it loses its valuable real-time quality.

- Another major building block is the development of an optimisation system that minimises the production and distribution of redundant data and ensures as far as possible that data are produced in accordance with the spatial and temporal requirements of the NMS. This is not an easy task and is also one being undertaken on a cooperative regional basis by some countries. This is also highly suitable for controlling data produced beyond the boundaries of the NMS country, ie. in the international arena. Systems are being developed in some regions so advice can be provided if required. A very effective basic optimisation system can be developed by simply using controlling functions within the onboard software. Another method takes advantage of the uplinking command function of the ACARS communications system to each individual aircraft. As mentioned earlier, the E-AMDAR group is offering to provide a global optimisation service but this needs the full agreement of the participating national airline.

- The final component is a system to archive observational data at the national and possibly, regional level.

NMS Tasks

7. The following tasks are the responsibility of the NMS:

- The NMS will need to conduct an analysis of its operational requirements for AMDAR data and how it will use and distribute the data. Typically, data are used:

- to provide upper air observations in close to real time to operational forecasters for updating aviation, severe and public weather forecasts;
- as an important input to numerical models;
- for forecast verification.
- for distribution to other NMSs globally via the WMO GTS

- System design and performance specifications will be required for presentation and discussion with the airlines.

- The preparation of a contract or at least some form of Memorandum of Understanding or agreement document for the provision of an AMDAR service by the airlines. In some countries, this takes the simple form of an exchange of letters. In others, a series of formal contracts are established for the various components. Most airlines are happy to discuss data ownership (or intellectual property rights), distribution and use but generally do not want to have these items included in detail in a formal sense in any contract. However, all these issues need to be addressed.

- Arrangements or a contract with a communications provider to pass data from either the airline or one of the aviation communications providers. Both major aviation communications provides also provide ground based data services.

- Specification and development of the various components of the system.

- Development of operational systems to use and display AMDAR data within the NMS.

Costs

8. The following items are provided as indicative to the possible range of expenses likely to be experienced by an NMS developing and operating an AMDAR program. Experience shows that each country and individual airline has its own way of undertaking the development. Costs will vary widely ranging from no-cost to very expensive. Much depends on the working relationship between the NMS and the airline and in particular, whether the airline wishes to make a profit from the work and service it provides. All costs are given in US dollars.

Development

9. As mentioned earlier, software is generally available free of charge from two main sources. A small charge is sometimes made to make appropriate adjustments to suit the particular aircraft type and model and any other special configuration settings. However, if software is not available to suit a particular aircraft type or model or the relevant avionics hardware, then it may be necessary to arrange for a software development contract with an appropriate avionics software provider. The cost for development of a complete software package can range between $5,000 and $40,000 using one of the two preferred software specifications. The range is large because the cost depends on the cooperation and understanding of the particular airline involved and whether it is doing the work at full commercial rates or more out of interest and support for AMDAR noting the airline itself will be an immediate beneficiary of the data.

Configuration and Installation

10. All AMDAR software must be configured to suit the particular airline's systems and operational requirements including the type and model of the participating aircraft, specific peculiarities of each individual aircraft and the preferred operational defaults and settings required by the data user, usually the National Meteorological Service (NMS). A charge per aircraft fleet including installation is normally applied by the airline for this work and can vary according to the size of the aircraft fleet. The cost also varies according to airline practices but typical values per aircraft range from $200 to $1000 and if the airline charges per fleet, the cost can range from $6000 to $40,000. At least one small avionics software and communications company provides a range of services at very reasonable rates to assist airlines prepare and configure software and/or full implementation across aircraft fleets. Arrangements can be made for this to be done at their offices or on site with the airline as a full turn-key operation for a fee of around $6000.

Communications

11. The principle operational cost of any AMDAR system is in aircraft communications. The major cost component arises from the transmission of the meteorological data to the NMS. There is a range of methods by which this is achieved but the most common method is for the aircraft to transmit the data via VHF link to a ground receiving station operated by one of the small number of companies providing regional or global communications services to the aviation industry. If the aircraft is operating out of range of a ground receiving station the data are either stored on board for later transmission using the VHF system, or more commonly now, the data are transmitted through the satellite arm of the communications system. The satellite mode is significantly more expensive than the VHF system by a factor of between 5 and 10 but it is normally the only option available over oceanic and some remote areas of the world. A second global option being developed using HF has been adopted by some airlines. It is cheaper than the satellite system but is still 2 to 3 times the VHF cost.

12. Data are normally passed by the communications provider through global circuits to the participating airline that in turn, reformats the data and passes it via one of many available ground based communications providers to the NMS. There is an additional but generally small charge for this service. In some cases where the airline and the NMS have special arrangements, the data can be passed direct to the NMS by the communications service provider without first going to the airline.

The cost of delivering data from an aircraft to the NMS generally ranges between 1 to 12 US cents per observation via the VHF system. The median value of all current operational systems is 4 cents per observation. An observation typically consists of time, horizontal and vertical position, phase of flight, and the observed elements of temperature, wind speed and direction, a quality flag, and in some cases, humidity and/or turbulence. The cost is largely dependent on several factors:

- The contractual arrangements between the particular airline and its communications provider;
- The volume of communications traffic generated by the airline;
- Whether the airline is aiming to make a profit from the NMS;
- The airline's cooperation in not passing on the full marginal communications charges.

Cost Summary

- Provision of initial AMDAR software: $Nil
- Initial software preparation, integration into the avionics software package and installation on the first fleet of aircraft (eg B737): $Nil - $40,000
- As above on subsequent fleets of aircraft (eg, B767, A320,etc) $Nil - $15,000
- Establishment of a communications line with the airline: $5,000
- Purchase or development of the ground-based data processor: $45,000
- Development of Quality monitoring and reporting system: $Nil-highly variable
- Development of operational infrastructure by airline (comms and billing)$Nil - $25,000

Operational (Annual)

- General system maintenance per aircraft fleet $Nil - $2,000
- Maintenance of data switching and billing by airline $Nil - $3,000

Operational (Once off)

- Reconfigure software per aircraft as required $Nil - $75
- Removal and decommissioning of software per aircraft $Nil - $3,000

Communications

- VHF transmission of data to NMS: Varies between airlines- 1 to 12 cents per observation. A typical figure is 4 cents per observation,
- A meteorological profile contains about 30 observations with reporting at around 100m intervals in the boundary layer. Observations at cruise level are made at a reporting frequency of 7 minutes.
- A typical aircraft produces between 150 and 400 observations per operational day at cost ranging from $6 to $16.
- SATCOM transmission of data: typically 4 to 5 times the VHF cost.
- HF transmission of data: typically 2 to 3 times VHF cost.