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# THE DEVELOPMENT OF THE CANADIAN AIRCRAFT METEOROLOGICAL DATA RELAY (AMRAD) PROGRAM - AN UPDATE

Gilles Fournier *
Environment Canada, Ottawa, Canada

## 1. Introduction

Upper-air data are a critical input for numerical forecasting, climate and air quality models, and are useful for weather forecasting and for validating satellite retrievals. There are a number of sources of upper-air data: radiosondes, satellites, ground-based weather radars, and wind profilers are currently operational upper-air observing systems. While automated aircraft reporting systems (such as AMDAR (Aircraft Meteorological Data Relay), GPS Meteorology systems, aerosondes, dropwindsondes, ground-based doppler lidars, etc., are new observing systems that are being developed and becoming operational.

Currently, the core source of upper-air data is the global radiosonde network (www.wmo.ch), which includes the Canadian radiosonde network operated by Environment Canada that currently consists of 31 regular radiosonde stations with balloon launches twice daily.

With the advances in weather modeling and computer capabilities, high resolution upper air observations are required. Very cost effective automated meteorological observations from commercial aircraft are an excellent means of supplementing upper-air observations obtained by conventional systems such as radiosondes. According to WMO AMDAR Panel (2002), aircraft Meteorological Data Relay (AMDAR) systems have been available since the late 1970s when the first Aircraft to Satellite Data Relay (ASDAR) systems used specially installed processing hardware and satellite communications. Subsequently, by the mid-1980s, new operational AMDAR systems taking advantage of existing onboard sensors, processing power and airlines communications infrastructure were developed requiring only the installation of specially developed software.

Today, there are well established regional AMDAR programs in Australasia, Europe, Southern Africa and the United States involving 10 countries and 15 airlines and new national programs in Canada, Japan, Saudi Arabia and Hong Kong are being developed. From these programs, over 130,000 observations are reported daily on the Global Telecommunication System (GTS).

* Corresponding author address: Gilles Fournier, Senior Environmental Monitoring Scientist, Atmospheric Monitoring and Water Survey Directorate, Meteorological Service of Canada, 373 Sussex Drive, Block E-102, Ottawa, Ontario, Canada K1A 0H3

In this paper, the development of the Canadian AMDAR Program will be described, issues encountered will be discussed, and plans for the future will be provided.

## 2. Historical Background

While the Canadian radiosonde network exceeds the World Meteorological Organization's (WMO) accuracy standards for aerological observations, it does not meet the recommendations for spatial and temporal coverage by upper-air land stations, and expanding the core network of radiosondes would not be cost-effective. As the best technology to provide such observations in the short-term and at low risk is through the use of commercial aircraft, an operational AMDAR program is being developed in Canada and forms a cornerstone of the modernization of the Canadian Upper Air Observing Program.

After a Business Case on the benefits of a Canadian AMDAR Program was presented to the Canadian air carriers in March 2000 (SYPHER: MUELLER International Inc. and Enviromet International Inc., 2000), the Meteorological Service of Canada (MSC) formed the Canadian AMDAR Program Implementation Team (CAPIT) to oversee all aspects of the development of the Canadian AMDAR Program. CAPIT membership includes Nav Canada, Canadian air carriers, a representative from the Forecasts Systems Laboratory of the National Oceanic and Atmospheric Administration (NOAA/FSL) and the Technical Coordinator of the WMO AMDAR Panel.

## 3. AMDAR Development with Air Canada Jazz

Air Canada Jazz (www.aircanadajazz.com) is the number one Canadian regional air carrier that resulted from the amalgamation of four regional airlines, Air Nova, Air Ontario, Canadian Regional and Air BC, a couple of years ago (Figure 1). In early 2000, Air Nova began the development of a datalink program based on Aircraft Communication Addressing and Reporting System (ACARS) for the management of its fleet of DHC-8 100 aircraft (the DHC-8 is also know as Dash-8). It was then timely to approach Air Nova with a request to investigate the possibility to implement an AMDAR capability using the Canadian AMDAR specifications. The Canadian AMDAR specifications are based on ARINC 620 Supplement 4 (www.arinc.com).

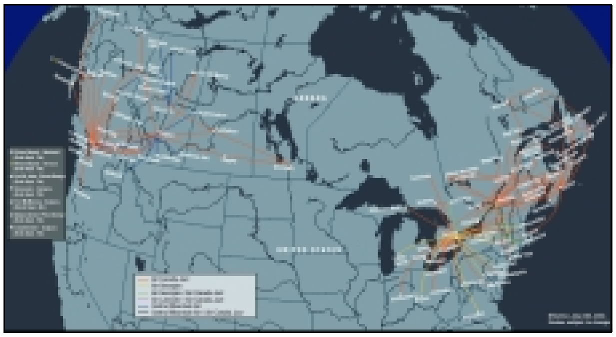

Figure 1. Map showing the routes serviced by Air Canada Jazz valid on 24 July 2002. The 21 Dash-8 aircraft service eastern Canada.

The work started promptly with the development of the Canadian AMDAR specifications into Universal Avionics Systems Corporation's (UASC) UniLink UL-601 version 13.1, the avionics of the Air Canada Jazz' DHC-8 aircraft. The first aircraft loaded with UL-601 13.1 began reporting in the fall of 2001 but, unfortunately, the data received at the Canadian Meteorological Centre (CMC) could not meet all AMDAR requirements because the system could not handle the analog nature of the DHC-8 100 model.

As the problem could be partly resolved through software, UASC was subsequently contracted to upgrade the UL-601 system to version 13.2. Software upgrade 13.2 was completed in the spring of 2002 and first data were received by CMC in mid-June 2002. However it is Barometric Altitude ($B_{Alt}$), not Pressure Altitude ($P_{Alt}$) that is reported for altitude 18,000 feet and below.

Currently 21 DHC-8 100 aircraft servicing eastern Canada are reporting AMDAR data (pressure, temperature, wind speed and wind direction) to CMC through the Aeronautical Fixed Telecommunication Network (AFTN) operated by Nav Canada. Meanwhile, CGP Associates Ltd., a company from UK that had developed the European EUMETNET – AMDAR Data Acquisition System (E-ADAS) was contracted to develop the Canadian – ADAS (C-ADAS). C-ADAS has been operational at CMC since mid-July for real time acquisition of the Canadian AMDAR data, data format handling and transformation and basic quality control, and, eventually, it will be used for the transmission of FM-94-BUFR AMDAR data onto the GTS and MSC's regional centres. For aircraft observations taken below 18,000 feet, C-ADAS uses QNH values obtained from METARs to convert $B_{Alt}$, to $P_{Alt}$.

Figure 2 presents the architecture of the AMDAR system that was developed with Air Canada Jazz. It can be noted from this figure that CMC receives the data directly from Air Canada Jazz and that there is provision for a feedback mechanism between CMC and the airline.

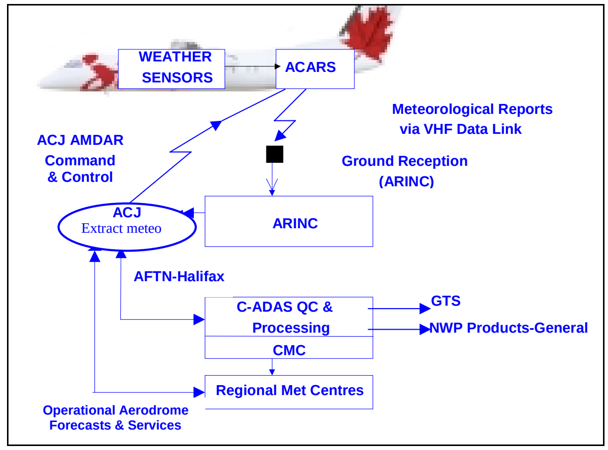


Figure 2. Schematic presenting the AMDAR data flow for the Canadian AMDAR Program with Air Canada Jazz.

Another very important component of the system is the AMDAR data Command and Control system (Figure 2) that was implemented to reduce unnecessary duplications and associated communication costs (MacKay, 2002). This system is operated by Air Canada Jazz in coordination with CMC.

The basic rules of the Command and Control system are the following:

- Only one aircraft within reports ascent data for each airport per hour.
- A descent should never eliminate an ascent, but an ascent can disable a descent.
- Only one aircraft will report descent data per 2 hours per destination.
- Ability to permanently request mandatory reporting of ascent or descent from a station.
- Ability to specify that the last flight per calendar day will always report ascent and or descent data, regardless if it falls within the specified window.
- Ability to specify range of flight numbers to disable totally (e.g. test flights).
- Diversion information should disable further data feed.
- Modular programming to allow changing of parameters without major re-programming. (i.e. ability to change time specifications, etc.)
- Ability to create a table of airports where auto disabling can be specified by time (to avoid duplication with other airlines).
- Ability to indicate an encrypted aircraft ID, unique to that aircraft, that is controlled by Air Canada Jazz.
- Ability to transmit in ARINC 620-4 format to CMC.
- Ability to accept an external signal for manual AMDAR data on/off selection from an external source (for future enhancement ability).

The Command and Control system uses these basic rules and automatically sends uplink commands to aircraft to enable/disable reporting for specific phases of flight. This system has the potential for targeting AMDAR observations based on meteorological conditions.

The maps of North America in Figure 3 and 4 show AMDAR observations received by CMC for all observations at all levels and up to 3 km respectively, over a 24-hour period from 15 July 20 UTC to 16 July 19 UTC. In green are the US AMDAR data and in violet, the Canadian AMDAR data.

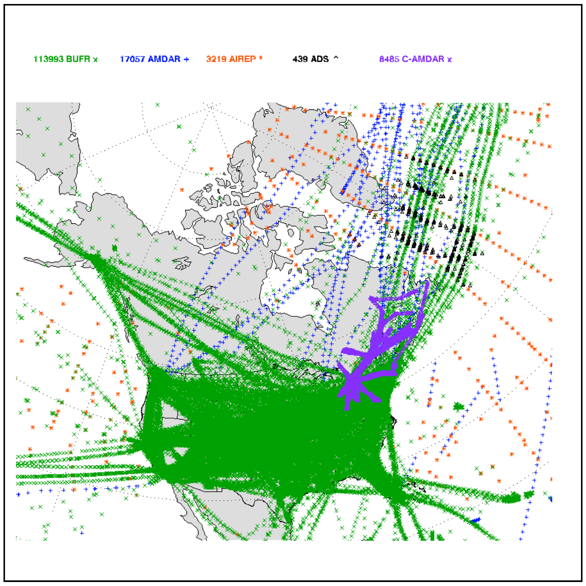


Figure 3. Map showing AMDAR coverage for all levels.

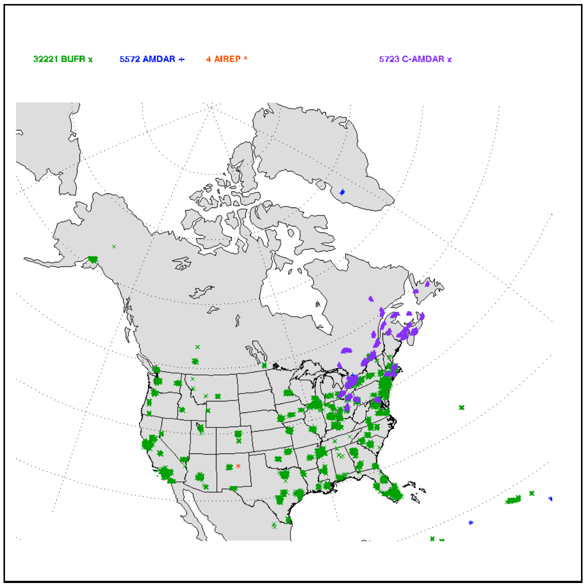


Figure 4. Map showing AMDAR coverage for levels up to 3 km.

Figure 4 practically shows where airport soundings (profiles) of AMDAR data were collected over a 24-hour period from 15 July 20 UTC to 16 July 19 UTC. While the USA is very well covered with 6 major airlines involved, these service the major hubs. The advantage of a regional airline is that its aircraft fly shorter flights and soundings are provided from many more airport locations.

The current observing requirements are that during ascent, the rate of observing begins as once every six seconds—giving forecasters a snapshot of atmospheric conditions every hundred metres. It slows to once every three minutes when the aircraft reaches cruising altitude, and then speeds back up to once a minute during descent. These default observing requirements are modifiable within their allocated ranges through uplink commands.

Since mid-July 2002, CMC has been evaluating the Canadian AMDAR data to make sure that the data are of adequate quality before CMC makes the data available to the world through the GTS (Verner, 2002). Unfortunately, since the beginning of data acquisition in mid-July, a positive temperature bias of 2-4C (Figure 5) has been observed with the Canadian AMDAR data generated by the 21 DHC-8 100 aircraft. The same type of temperature bias was observed by the European E-AMDAR with DHC-8 Q400 aircraft operated by SAS (Scandinavia) before they were blacklisted. A deeper investigation is pointing to an inability of the temperature probes installed on the DHC-8 aircraft to meet the AMDAR requirements. The temperature bias also leads to a degradation of the measured wind.

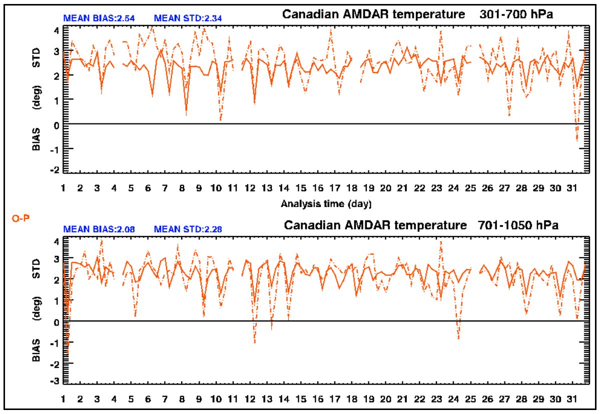


Figure 5. Observed minus first guess statistics for the Canadian AMDAR temperature in August 2002. A mean bias of +2.54C is observed between 301-700 hPa (upper graphic), and +2.08C between 701-1050 hPa (lower graphic).

Air Canada Jazz has plan to upgrade its entire fleet of DHC-8 100 and 300 aircraft, i.e. 90 aircraft total, with Universal Avionics Systems Corporation's UniLink UL-700/701, new Air Data Computers (ADC), and new temperature probes (MacKay, 2002). The new ADCs and temperatures probes should eliminate the temperature bias, which will in turn render the wind outputs more accurate. The upgrade should occur at a pace of 4 aircraft per month over the period February 2003 to December 2004.

In addition, Air Canada Jazz operates 10 Canadian Regional Jets (CRJ) 200 and has plan to increase this number to 20 in the near to mid term. The ACARS system will be operational on these aircraft in the first quarter of 2003, likely using Collins avionics, and the AMDAR message set has been specified for these aircraft, using the Canadian AMDAR specifications.

**4. AMDAR Development with First Air**

A partnership is being developed with First Air (www.firstair.ca) for the development and implementation of a non-ACARS based AMDAR system for the data sparse north (Figure 6). Talks with First Air for the implementation of the AMDAR program started in December 2000.

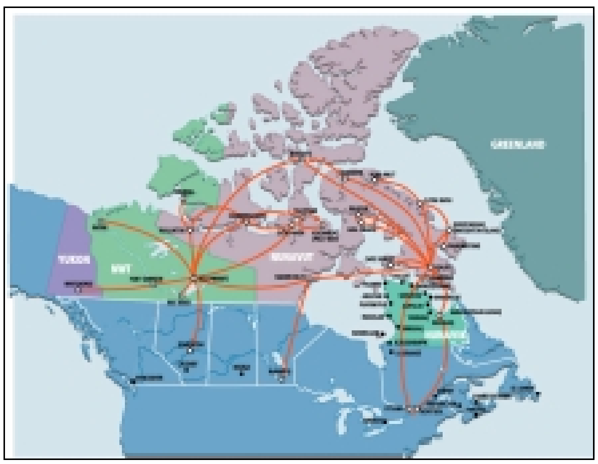

Figure 6. Map showing First Air scheduled route structure, providing significant coverage in the sparse north of 60N area. A certain number of the high arctic locations get daily, or close to daily service. There is no conventional VHF datalink network in this area. This is where the satellite technology comes into play.

First Air has an agreement with DATATRACK and InteliSys to develop a system for transmitting GPS positional information and small messages from its aircraft using the Orbcomm constellation of Low Earth Orbiting (LEO) communications satellites. Information will be sent by e-mail via the Internet. The system was tested with success by First Air.

First Air was approached by MSC to see if the communications system they had been testing could be expanded to add AMDAR data reporting capability based on the Canadian AMDAR specifications. The answer was positive and consequently a contract was signed with First Air in July 2002 for the development of the AMDAR alternative communication system and deployment of the AMDAR capability on 16 aircraft servicing the northern communities. The contract has four phases, the three first phases in this fiscal year and the last one in the next fiscal year. The phases are analysis, development of a prototype, testing of the prototype, and deployment of 16 systems. First Air is actively working with InteliSys to have the three first phases completed by 31 March, 2003. The lab environment is currently under construction. A phase can only proceed if the previous phase gave positive results and funding is available. If everything goes well, Canada could have 16 First Air aircraft providing AMDAR data and soundings over the north in 2-3 years.

The aircraft proposed for reporting AMDAR data are:

- Four B727 aircraft (three combined passenger-freight models and one full freighter).
- Three B737 combined passenger-freight aircraft.
- Eight ATR-42-300 aircraft.
- One L382 Hercules freighter.

Figure 7 (Nourse, 2002) presents the overall concept of the AMDAR system being investigated. The plan is to use standard off the shelf components to take the weather data information, do some local processing on board the aircraft and then send the data via the Orbcomm network and the Internet to a data centre in Shediac, New Brunswick. There the data will be put into standard AMDAR format and sent on to MSC.

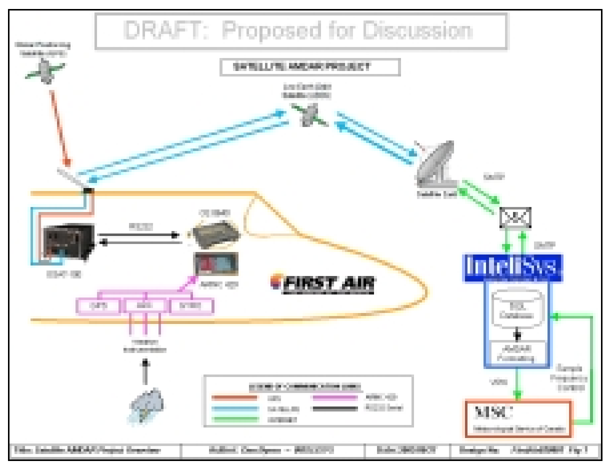


Figure 7. First Air AMDAR system concept.

To achieve minimal certification, First Air is purposely trying not to integrate the AMDAR system into aircraft systems. The AMDAR system will allow for fast tracking certification of installation and for rapid software development and changes.

Costs of satellite communications are 5-10 times those of VHF, thus what is required is a cost effective satellite communication system. Up until the fairly new LEO systems, satellite communication was extremely costly. The Orbcomm network was built to provide relatively cost effective, albeit slower speed and not always real time, data. The system has periodic “holes” in the constellation at higher latitudes that precess slightly each day at. Although they could be up to two hours the worst First Air has seen at extreme latitudes, both north and south have been about 20 minutes. The system has a store and forward capability to overcome this.

Obviously data compression and management are critical to maintain cost effectiveness. First Air is working on a number of options to eliminate unnecessary duplication of data and reduce communication costs to minimum (Nourse, 2002). This is why the data centre will put the information in standard AMDAR format in order to take every opportunity to compress the data stream from the aircraft. First Air also intends to pull rather than push the data. All of this will result in the implementation of a geo-spatial control or cubing (Figure 8). The entire airspace will be divided into three-dimensional blocks. Control over block size and sampling frequency will be given to MSC. The aircraft will be sending continuous position reports, when the management software determines that a sample is “due” from a given cube, the first aircraft entering it will be polled for a full AMDAR report. The next aircraft entering the cube will not be requested for a report until the designated time has elapsed.

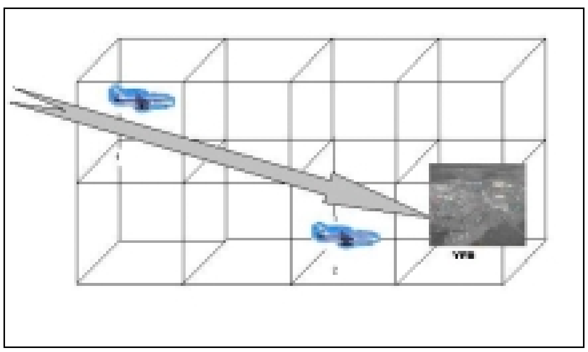

Figure 8. Geo-Spatial Control (Cubing) concept. Here aircraft number one is landing at Iqaluit ahead of aircraft two. Because both aircraft are close together in time, no reports will be polled from aircraft number two. It is estimated that with a time setting of one hour, up to a two thirds reduction in data traffic is possible.

Unfortunately First Air operates a mixed fleet and does not necessarily have a single solution available. This is part of the reason that it may be simpler and actually more cost effective to install an independent Air Data Computer on board these aircraft. This would allow to have only one software load rather than have to develop customized software and interfaces for each type of aircraft. It will also enhance the flexibility of the system.

**5. Other Activities**

Talks are proceeding with other Canadian air carriers, namely the major airlines, Air Canada and WestJet, to enroll them into the Canadian AMDAR Program.

Considerations are given to expand AMDAR capability but MSC will have to find alternative funding sources to fund development, certification and procurement of Water Vapor Sensing System-II (WVSS-II), turbulence reporting and icing reporting for the DHC-8, the ATR42 and the CRJ aircraft.

Other systems under investigation are TAMDAR (awin.larc.nasa.gov/abstracts/SensorTech/index.htm) by NASA and Otical Detection Systems (ODS), and AFIRS-Uptime (www.amscanada.com) by Raytheon - Aeromechanical Services Ltd. (AMS).

**6. Conclusion**

With the work Air Canada Jazz and the Meteorological Service of Canada have completed to date, any DHC-8 (models 100, 200, 300 or Q400) or CRJ operator in the world will be able to equip with AMDAR capable avionics from Universal Avionics or Rockwell Collins if they so choose, or any aircraft that equips with the UASC’s UniLink UL600/700 or Collins’ CMU 900.

Once the temperature bias issue is resolved on the DHC-8 aircraft, Canada will be increasing the amount of upper air data available over Northern North America substantially.

For the critical data sparse north, First Air and MSC are currently mapping all of aircraft data element availability and evaluating best value approach for the deployment of 16 AMDAR-capable aircraft by 31 March, 2004.

Other developers of AMDAR programs can hopefully learn from Canada’s successes and setbacks.

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