TAMDAR Sensor and System Overview

Airborne Real Time Atmospheric Data Collection and Reporting System

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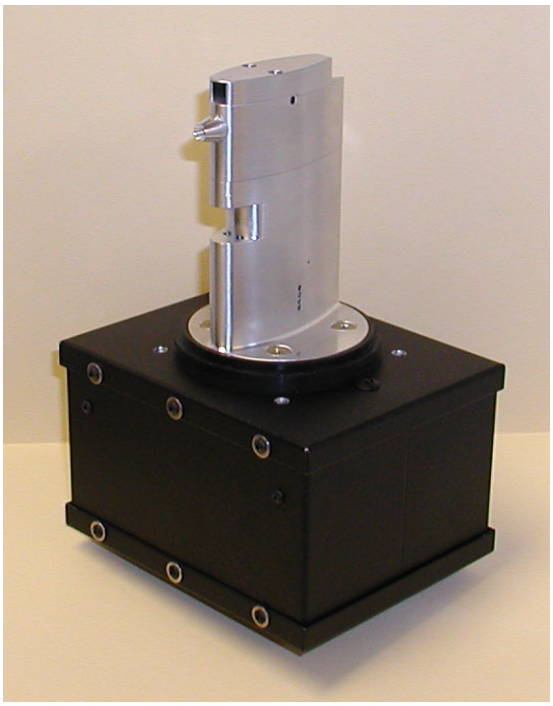
ABSTRACT

AirDat has developed, under a NASA-sponsored safety initiative, a unique multi-function atmospheric sensor called TAMDAR (Tropospheric Airborne Meteorological Data Reporting). This sensor was developed with input from NOAA/FSL, the FAA and the WMO to achieve both improved mesoscale modeling and aviation safety. The TAMDAR sensor offers a broad range of data collection capabilities, including humidity, icing and turbulence.

AirDat has coupled this unique sensor to a global satellite network and supporting data center. The data center processes, formats and distributes TAMDAR atmospheric data in effectively real time and can provide other services to aircraft fleet operators including electronic OOOI times, GPS tracking and text messaging. Deployment of TAMDAR sensors on commercial aircraft is now in progress.



The TAMDAR Atmospheric Sensor

INTRODUCTION

The TAMDAR system measures all key atmospheric parameters, provides operational flexibility and control, and is planned for deployment on an optimal mix of aircraft for maximum spatial and temporal data collection.

Key measurements performed by the TAMDAR sensor include:

- Humidity
- Pressure
- Temperature
- Winds Aloft
- Icing
- Turbulence
- Location, time, and altitude from built-in GPS

Plans also include possible future implementation of hazardous element and pollutant detectors into the basic sensor package.

AirDat's dedicated data center collects, QA's, processes, formats and distributes the TAMDAR atmospheric data in near real time. A two-way satellite communication system has been implemented to downlink TAMDAR data and uplink sensor commands; the TAMDAR sensor and data center can also support other communications architectures as required.

The combined data center and satellite communications system provide unique benefits for the operational TAMDAR system, including:

- Uplink commands to control and manage the data collection parameters
- Global coverage at any location and altitude
- Short latency — typically less than 15 sec from observation to ground display
- Near real time tracking and reporting of aircraft position (mapping software available)
- Airline operational support such as automated OOOI times
- Text messaging to and from the cockpit
- Potential for voice communication to and from the cockpit
- Air-ground-air data transmission via the data center (effectively air-to-air)
- Data stream flexibility (TAMDAR independent of aircraft communication systems)

The TAMDAR sensor has been flight tested for more than two years on several aircraft, including:

- NOAA P3
- UND Cessna Citation II
- NRL Twin Otter
- UND Piper Seminoles (5)

Flight tests have confirmed the quality of the TAMDAR data and the integrity of the AirDat satellite communications link and data center. A pre-production readiness review conducted by NASA, with participants from FSL and NWS, concluded that the TAMDAR sensor was ready for deployment.

NASA is supporting regional deployment of TAMDAR sensors in the Great Lakes region in 2004. The TAMDAR sensor has been certified on the Saab 340 aircraft that will be used in the regional deployment. Certification has also been initiated for regional jets, and favorable discussions have been held with several carriers.

In the USA, AirDat's goal is to equip approximately 1500 aircraft with TAMDAR sensors. The TAMDAR fleet will emphasize regional airlines and package carriers whose aircraft fly at lower altitudes and can provide ascent/descent profiles into several hundred airports, though some larger commercial jets will also be equipped.

The TAMDAR system will supplement and help overcome many of the limitations of existing technologies, including radiosondes and ACARS (MDCRS), providing an expanded and enhanced data set. TAMDAR will provide improved spatial and temporal distribution of observations. Atmospheric data will include not just the temperature, pressure, and winds aloft measurements provided by ACARS (MDCRS), but also humidity, icing and turbulence. Ascent and descent profiles will be gathered at a significantly larger number of major and minor airports.

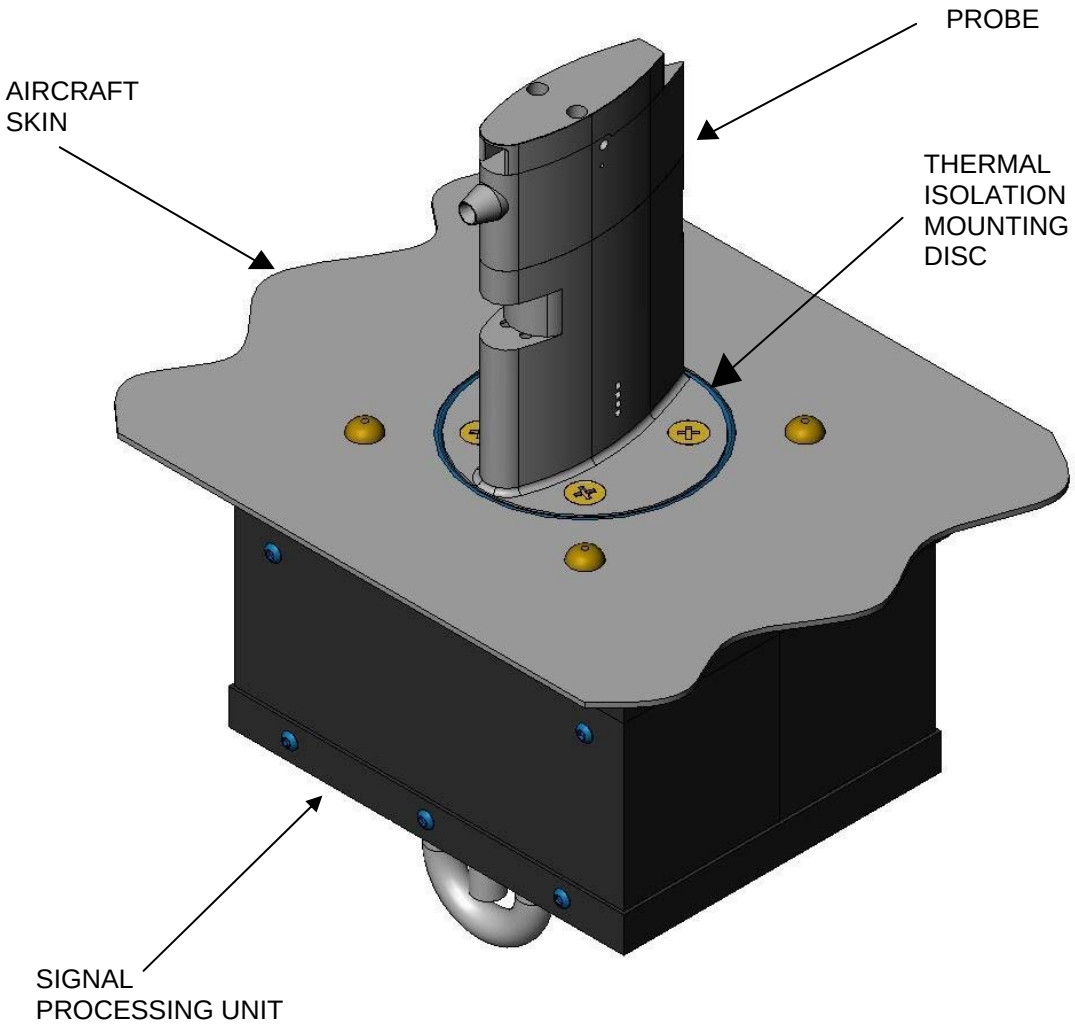
The AirDat satellite network and data center can fully support international deployment of TAMDAR sensors, providing all of the same features available in the continental United States.

TAMDAR SENSOR AND SYSTEM OVERVIEW

The TAMDAR sensor is a lightweight (1.5 lb.), low drag (0.4 lb. @ 200 knots), low power device designed for easy installation and retrofit to existing aircraft. The sensor is primarily a stand-alone device that does not require interaction with primary or critical aircraft systems, simplifying certification requirements significantly.

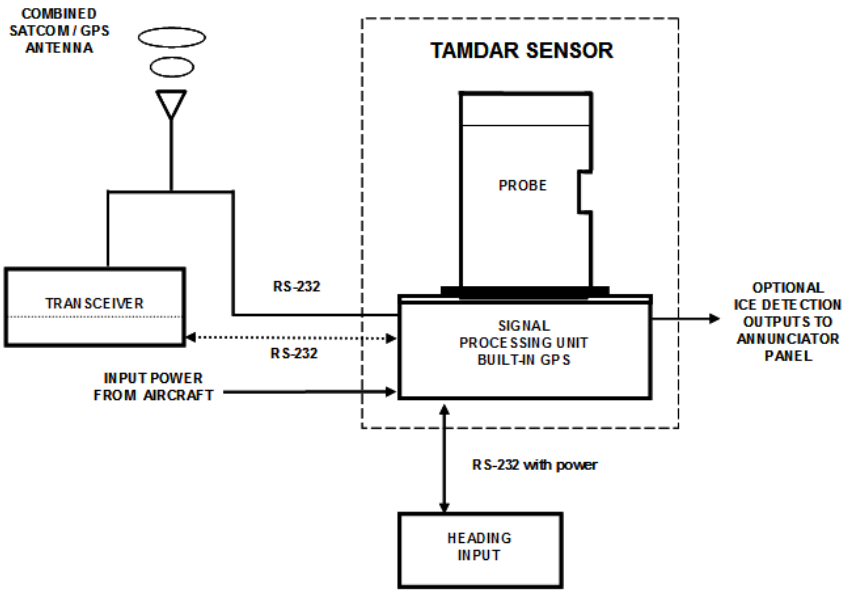
The sensor's signal processing unit processes, formats, and digitizes atmospheric data for transmission to the ground. The sensor interfaces directly to an inexpensive communications transceiver, eliminating the need for additional aircraft computer processing and expensive communications management units.

The basic components of the TAMDAR sensor are illustrated below. The sensor consists of an airfoil shaped probe that extends through the aircraft skin into the airflow, and a microprocessor-based signal processing unit inside the aircraft. The probe incorporates de-icing heaters, and is thermally isolated by a thermal isolation disc.



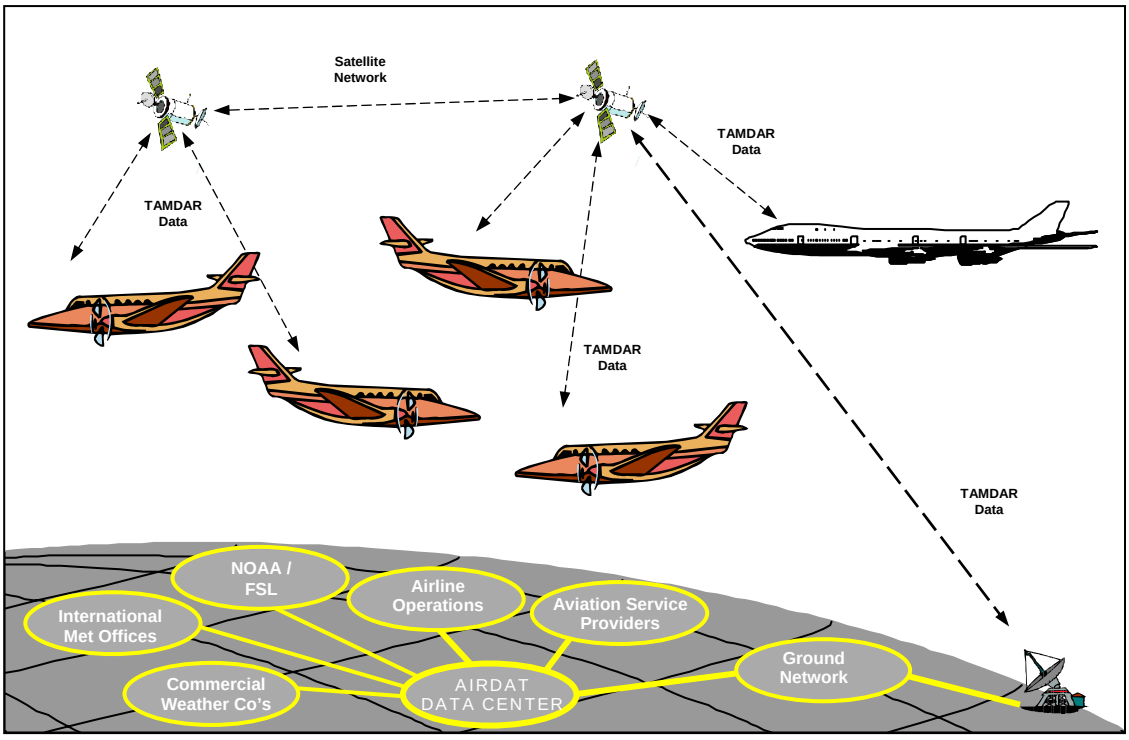
THE TAMDAR SENSOR

A typical TAMDAR aircraft installation is illustrated below:



AIRDAT COMMUNICATIONS STRUCTURE

The AirDat data center can support most communications architectures. The drawing below illustrates the communications structure utilizing AirDat's satellite data communications network:

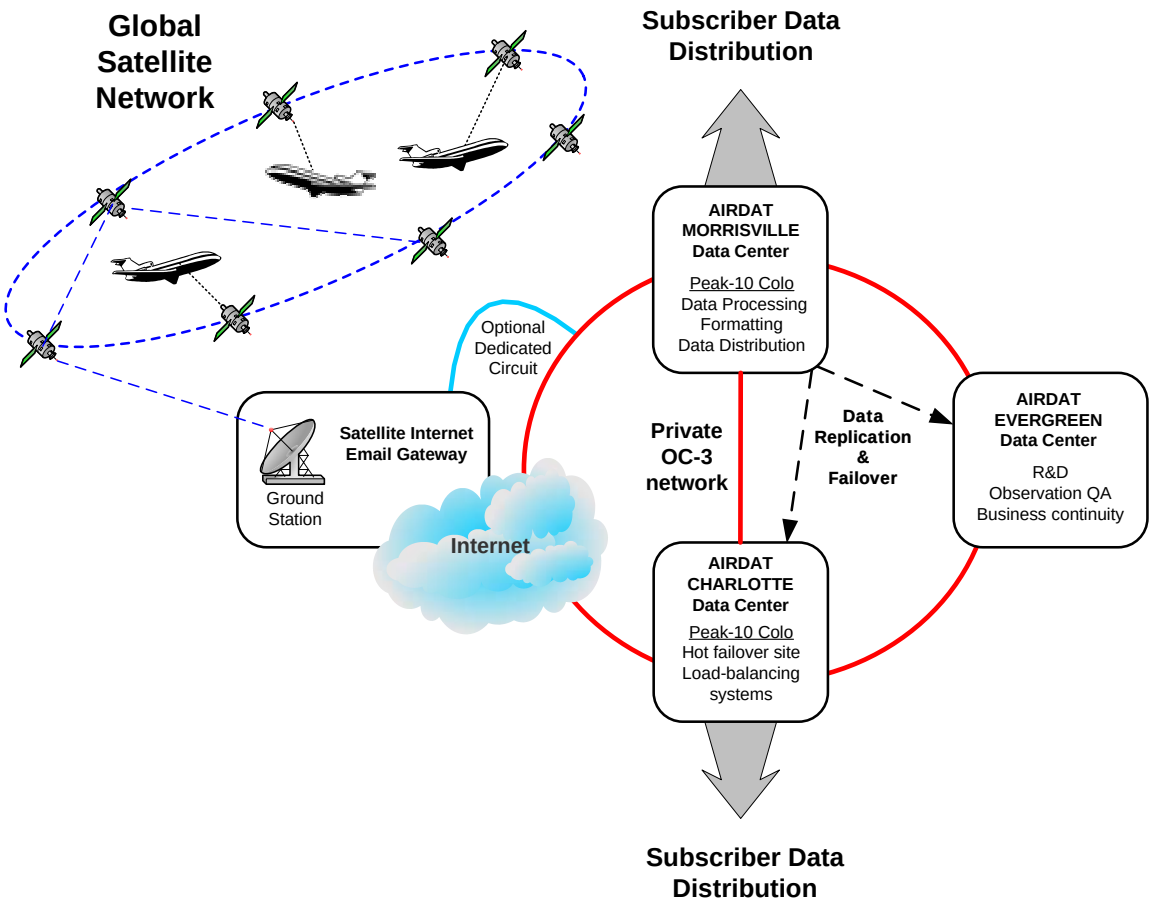


AIRDAT DATA CENTER

AirDat has established a global data center to receive and process the downlinked atmospheric observations, to format and relay the data to end users, and to provide ongoing lifecycle management of the TAMDAR network including sensor quality monitoring for sensors operating anywhere in the world. Complete TAMDAR data communication and data center services are available, including:

- Down-linking all TAMDAR observation data
- Automated gross quality monitoring and pre-processing of data
- Screening and sorting of observations by certain specified parameters
- Data archiving and disaster recovery
- TAMDAR sensor monitoring
- Distribution of data in AirDat standard format via secure internet connection (VPN) to a subscriber's site.
- Custom formatting and connectivity options are available
- 7/24/365 operations with subscriber help desk support

AirDat data center operations include 100MB+ Internet bandwidth with multiple redundant paths across geographically dispersed locations. The data centers have redundant Internet, power and generator facilities, with data vaulting and offsite storage.



TAMDAR FLIGHT TESTING

The TAMDAR sensor has undergone over two years of flight testing on several aircraft types. Flight test results have been used to refine the final TAMDAR product. The photos below illustrate TAMDAR installations on four test bed aircraft, including the NOAA P3.

NOAA P3

UND CESSNA CITATION II

NRL TWIN OTTER

UND PIPER SEMINOLE

The NOAA P3, UND Cessna Citation II and NRL Twin Otter are all fully instrumented research aircraft. These aircraft have a suite of reference instrumentation that was used to calibrate and verify the performance and accuracy of the TAMDAR sensor.

In addition, the UND Cessna Citation was flown concurrently with two radiosonde ascents; flight data substantiated the accuracy of the TAMDAR sensor. The Citation was also flown in support of the THORpex/Atlantic-TOST experiment (Nov-Dec 2003), with TAMDAR data transmitted to the data center and distributed to interested parties in near real time (demonstrating latencies averaging 8 seconds).

Five UND Piper Seminoles have been fitted with TAMDAR units. All Seminoles are transmitting flight data via the data center for distribution in near real time. The TAMDAR sensors are performing consistently and meeting requirements.

TAMDAR sensors are now being installed on 64 Saab 340 passenger aircraft.

PRESSURE-BASED OBSERVATIONS

The TAMDAR sensor was designed to meet requirements defined by NASA, NOAA/FSL, and the World Meteorological Organization (WMO). The data output format meets the unique needs of TAMDAR, while maintaining compatibility with US ACARS and international AMDAR standards.

TAMDAR atmospheric observations are based on pressure, rather than time, intervals during the ascent and descent phases. Time defaults are provided for portions of the flight when the aircraft is not significantly ascending or descending. Smaller aircraft, in particular, might experience flight mode shifts several times during a flight, providing useful data but making identification of flight mode less relevant than in the present time-based ACARS system.

The current pressure-based system with time defaults as defined with input from FSL and WMO:

Pressure-based observations:

- Initial ascent and final descent observations are made at 10 hPa (300 feet) pressure intervals up to 100 hPa (3000 feet) above ground level.
- Observations more than 100 hPa (3000 feet) above ground level are made at 50 hPa intervals.
- Pressure intervals, and the altitude at which the transition is made between high resolution and low resolution observations, are adjustable by remote command.

Time defaults:

- If an observation has not been made below 20,000 feet (465 hPa) for three minutes, then an observation is triggered by time default
- If an observation has not been made above 20,000 feet (465 hPa) for seven minutes, then an observation is triggered by time default
- Time defaults are adjustable by remote command

All intervals and defaults are remotely adjustable from the data center.

TAMDAR PERFORMANCE OBJECTIVES

The charts below describe the performance objectives of TAMDAR as defined by NASA and NOAA/FSL. The TAMDAR sensor is meeting these objectives.

MEASURED PARAMETERS; AIRCRAFT ALTITUDES TO 50,000 FEET

Parameter	Range	Accuracy	Resolution	Latency (See Note 1)	Comments
Pressure	10 -101 kPa	3 hPa	0.05 hPa	10 sec	See Note2.
Temperature	-70 to +65°C	±0.5°C	0.1°C	10 sec	
Humidity	0 to 100%RH	±2% static ±5% (typical) ±10% (typical)	1% (RH>10%) 0.1% (RH<10%)	10 sec	Dual RH sensors Below Mach 0.4 Mach 0.4 - 0.6
Heading	0-360°	±3°	0.1°	10 sec	@ < 30° pitch & roll
Ice Detection		0.020 inch			

DERIVED PARAMETERS; AIRCRAFT ALTITUDES TO 50,000 FEET

Parameter	Range	Accuracy	Resolution	Latency	Comments
Pressure Altitude	0 – 25,000 ft.	±150 feet	10 feet	10 sec	See Note 2
Pressure Altitude	25,000 – 50,000 ft.	±250 feet	10 feet	10 sec	See Note 2
Indicated Airspeed	70-270 knots	±3 knots	1 knot	10 sec	See Note 2
True Airspeed	70-450 knots	±4 knots	1 knot	10 sec	See Note 2
Turbulence (eddy dissipation rate--$\in^{1/3}$); Peak and Median	0-20 $cm^{2/3}$ sec^{-1}			3 sec	See Note 3. Reported as single encoded character (see TAMDAR Data Format).
Winds Aloft		± 4 to 6 kt vector magnitude error	1 knot, 1 deg	10 sec	See Note 4. Accuracy depends on relative magnitude and direction of vectors.

1. 10-second latency is caused by digital filtering of the data as recommended in the AMDAR reference manual.
2. Accuracy specified for angles of attack less than 30°.
3. Turbulence determination: calculation of eddy dissipation rate in accordance with MacReady. Atmospheric Calculated from 32 point DFT of TAS (3 sec block).
4. Winds aloft calculation will require use of GPS and magnetic heading.

SUMMARY

The combination of the TAMDAR sensor and global satellite communications infrastructure, integrated with a dedicated data center, offers an opportunity to significantly improve the collection of atmospheric data for weather forecasting and pilot information. The system can also provide useful operational support to aircraft fleet operators, including OOOI times, GPS tracking and text messaging. The equipment and infrastructure described herein are operational today and available for demonstration upon request.

APPENDIX:

TAMDAR Mechanical/Electrical Specifications

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APPENDIX

TAMDAR MECHANICAL/ELECTRICAL SPECIFICATIONS

Patented Ice Optical Sensing Technology	Microprocessor based pulse modulation, utilizing high power LED's emitting in the infrared range
Operating Limits	-70F to +65C, Altitude 50,000 feet, Humidity 0-100%
Probe Mechanical Specifications	Airfoil Type: 4.25" Long, 2.25" Chord L, 0.75" Chord W, 6061 T6 anodized aluminum. Quartz optical filters. Approximate Weight: 1.5 lbs Drag: 0.5 lb at 200 knots
Electronics Module Mechanical Specifications	W6.25" X D5.25" X H3.25 (not including connectors) Approximate Weight: 1.0 lbs
Power Requirements	12 to 35 VDC, 6 Watts average electrical load de-icing heaters not engaged; 300 Watts electrical load de-icing heaters engaged @ 28VDC input
Measurement Sampling Rate	10.7 Hz for sensors, 0.333 Hz for turbulence. Data (except that used for the turbulence calculation) is filtered with a 10 sec response IIR digital filter.
Data Output Observation Period	See "Observation and Reporting Intervals" section
Serial Ports	3 RS-232
Weight	Probe and electronics module approx. 1.5 lb
Design Life	Probe: 20,000 hours. Electronics Module: 50,000 hour MTBF