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AUTOMATED METEOROLOGICAL DATA FROM COMMERCIAL AIRCRAFT VIA SATELLITE - PRESENT EXPERIENCE AND FUTURE IMPLICATIONS

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AUTOMATED METEOROLOGICAL DATA FROM COMMERCIAL AIRCRAFT VIA SATELLITE - PRESENT EXPERIENCE AND FUTURE IMPLICATIONS

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ABSTRACT

The National Aeronautics and Space Administration has developed a low-cost communications system to provide meteorological data from commercial aircraft, in near real-time, on a fully automated basis. The complete system including the low profile antenna and all installation hardware weighs 34 kg.

The prototype system has been installed on a Pan American B-747 aircraft and has been providing meteorological data (wind angle and velocity, temperature, altitude and position as a function of time) on a fully automated basis for the past several months. The results have been exceptional. This concept is expected to have important implications for operational meteorology and airline route forecasting.

BACKGROUND

A number of recent events have emphasized the fact that man must intensify his efforts to improve his understanding of weather and climate if he expects to maintain his present economic position. It is not now known if the fluctuations in weather we are experiencing are part of a "normal" pattern or if important changes in climate are beginning to occur. However, it is clear that we must sharpen our analytical techniques and expand the present global data base if we expect to improve our predictive capability for weather and our understanding of the vagaries of climate. Figure 1 shows the current availability of upper air data on a world-wide basis. Over most of the globe, the present data base is inadequate or at best marginal. We need to begin to improve this situation. Efforts are now being made to use satellites to fill the data void. However, their present sensor resolution is insufficient to meet even minimal requirements for both temperature and winds in critical areas of the tropics and the southern hemisphere. It is hoped that this situation will improve as new satellite instruments are developed in the future. For the present, however the major question still remains, how can we improve the meteorological data base in areas of the world which are either sparsely inhabited or covered by water?

Recently, several people (1,2) have pointed out that commercial aircraft which carry Inertial Navigation Systems could provide a significant improvement in the present meteorological data base in the tropics and the southern hemisphere as well as a reference level for satellite calibration. The value of this proposal was demonstrated during an international meteorological experiment (3) in 1974 and again in 1976, where the data was provided on magnetic tape for research purposes. The next step (and the subject of this paper) was to develop a communications system to provide this data from aircraft via satellite relay, in near real-time, to meet the needs of operational meteorology.

INTRODUCTION

Over 500 Boeing B-747 and Douglas DC-10 aircraft equipped with Inertial Navigation Systems (INS) fly international air routes each day. Many of these routes are in the data sparse tropics and southern hemisphere. The INS provides high resolution data on wind angle and velocity as well as aircraft position while the Air Data Computer (ADC) provides information on temperature and altitude. These data are available on a fully automated basis and require no flight crew participation. The importance of this information to meteorology (4) has already been established; but there remains the challenge to provide this information to a national meteorological center in operational time and to develop procedures to process and utilize this data most efficiently.

In order to meet part of this requirement, the National Aeronautics and Space Administration has developed a low-cost communications system to provide meteorological data from commercial aircraft, in near real-time, on a fully automated basis. The communications system called ASDAR (Aircraft to Satellite Data Relay) consists of a transmitter, receiver, digital interface unit and power supply. The complete system including the antenna and all associated installation hardware weighs about 34 kg. Pan American Airlines, under contract to NASA, has developed the procedures (including a field modification kit) for the installation of an ASDAR system on a B-747 aircraft and has obtained Federal Aviation Authority certification.

The first ASDAR system has been installed on a Pan American B-747 and has been providing meteorological data (wind angle, wind velocity, temperature, and altitude as a function of latitude, longitude and time) on a fully automated basis for several months. A few minor technical problems have been experienced (see section entitled Problem Areas) which proved to be more annoying than difficult because it resulted in a reduced flight schedule. However, in the main, our results to date have been exceptional. We have been able to transmit data from the aircraft to the satellite with an elevation angle as small as 0° and a single satellite has provided coverage from 20° to 180° west longitude. By early 1978 there will be four synchronous meteorological satellites in orbit providing the potential for global coverage from ASDAR equipped commercial aircraft.

ASDAR System Description

Figure 2 shows a block diagram of the prototype ASDAR system. The transmitter output is 80 W at 401 mHz and is controlled by a microprocessor in the digital interface unit. Data is transmitted at the rate of 100 bits/sec. A standard transmission consists of eight complete data sets and takes about 37 seconds to complete. The purpose of the 468 mHz receiver is to provide accurate time from the satellite. By synchronizing all aircraft to a single time source the time between aircraft transmissions can be minimized. This would provide for the maximum number of aircraft per satellite channel. If power is interrupted to the ASDAR system for any reason, transmission will not occur until a correct time update has been received and verified. The digital interface units provides an accurate time signal and stores all required information from the aircraft INS and ADC in the proper time sequence for transmission. A diplexer is also provided to prevent damage to the receiver during transmission, and a small preamplifier has been included to reduce signal losses resulting from a long cable run from the electronics bay to the antenna.

Figure 3 shows the complete ASDAR system, except for the antenna. The transmitter, receiver and digital interface unit is on the left and occupies a full ATR (air transport radio) box in the aircraft electronics rack. The front panel thumb-wheels and switches (normally covered with a plate) are used to accomplish the following:

(1) set the time for transmission (min/sec)

(2) identification number of ASDAR unit

(3) transmission rate (1, 2, 4, 8 transmission/hr); each transmission provides 8 data sets

(4) ground checkout of system

The power supply is on the right and it occupies a half ATR box. In the center foreground is the diplexer with the preamplifier behind it.

ASDAR Antenna

Figure 4 shows the prototype ASDAR antenna mounted on a B-747 aircraft. The antenna which is a Coplanar Stripline type is 20 cm wide, by 40 cm long by 1.9 cm high and is contoured to fit the aircraft fusalage. It is designed to provide for both transmission and reception and meets the following specifications:

	Frequency	Gain	Axial ratio
Transmit	401 mHz	2.0 dB	3.5 dB
Receive	468 mHz	1.5 dB	3.2 dB

These antenna specifications are for the production model and are somewhat better than was initially achieved for the prototype. The prototype antenna, however, performed extremely well as can be seen from figure 6. The antenna weighs about 2.5 kg and is easily mounted on the aircraft, requiring only about a 3 centimeter diameter hole for the connector. The installation kit developed by Pan American Airlines includes the antenna and all mounting hardware as well as detailed instructions designed for airline installation.

Operating Experience

Figure 5 shows a computer printout of ASDAR data as obtained from the National Environmental Satellite Service at Suitland, Maryland. This data was recorded when an ASDAR equipped Pan American B-747 was on the ground at San Francisco in preparation for a flight to Tokyo. Figure 6 shows the location of meteorological measurements made (during a six week period) from a single aircraft, with contours of constant elevation to the receive satellite, which was at 105° west longitude, superimposed. A time signal was provided by another satellite at 75° west longitude. This explains why no data was transmitted west of Hawaii. The ASDAR system was unable to get a time update on leaving Hawaii because the elevation angle between the aircraft and the satellite (75° W) was less than 0°. However on the Atlantic side, transmissions were being made successfully at elevation angles of less than -5°, because of early receiver lock-on from the satellite at 75° west longitude. Data was also received from as far north as 68° on Seattle to London flights. In the beginning meteorological information was transmitted hourly however this was changed to half hour intervals in an attempt to better define the area of coverage. The ASDAR system performed well during almost 2 1/2 months of unattended operation. This clearly showed that the system could meet our operational requirements and that there were no major technical problems.

Problem Area

The first problem experienced was a moisture leak at the antenna (after 2 1/2 months of flying). This has been corrected and no further difficulty is expected. A drift in transmitter frequency has also recently been discovered. This is being analyzed and elimination of this difficulty is expected shortly.

ASDAR System Modifications

A fully self-timed clock will be installed in all ASDAR packages replacing the present receiver. This will eliminate the requirement for time-code broadcasts from current satellites supporting the ASDAR data collection program. It is expected that this change will make it easier to implement the ASDAR program internationally. As a consequence, however, the clock on each aircraft will have to be reset about once every 12 months and perhaps even more important, the number of aircraft per satellite channel will be reduced. Presently with the prototype receiver system, a single channel can handle about 100 aircraft. The on-board clock reduces this number to about 30. If testing shows that the receiver is in fact the better approach, the design is such that the ASDAR system can easily be returned to the original configuration.

Present Plans

A major international meteorological experiment is scheduled to begin in December 1978 and last for 12 months. It is anticipated that perhaps as many as 15 to 20 ASDAR equipped aircraft will be in operation during this experiment providing important data from the tropics and the southern hemisphere in near real-time. In addition, these aircraft will be supplemented by 70 to 80 aircraft which will also provide ASDAR type data stored on magnetic tape. The same high quality, high resolution data that ASDAR provides will also be available in this case, but not in near real-time. This combined fleet will not only make possible a significant improvement in the research data base for this experiment from the tropics and the southern hemisphere, it will also provide an opportunity to evaluate this potentially new source of meteorological data over the full 12 months of the experiment.

Future Implications

Many aircraft which are used on international over-water routes carry INS. The present fleet of about 500 INS equipped jets is expected to increase with the trend toward larger aircraft. Meteorological data relay satellites such as Meteosat and Goes can provide the means for getting this data from aircraft to national meteorological centers in near real-time.

ASDAR will cost between 20 and 30 thousand dollars per system including installation (in quantities of 10 to 12). There are at least 200 INS equipped aircraft which transit the tropics every day. Each is essentially a meteorological data collection platform. An investment of about 5 million dollars could equip all 200 aircraft with ASDAR systems (including spares). This would provide about a 1000 percent increase in the number of meteorological reports (200 km resolution) coming from the tropics and the southern hemisphere! The impact of such an increase in the present data base could be of major importance not only to weather forecasting but airline flight planning as well. More accurate and timely windfield and temperature information should provide the potential for a better analysis and weather forecast. Since the airlines use this forecast to generate their own minimum time track flight plans, the availability of more accurate and timely windfield and temperature information can also be translated by the airlines into fuel savings. Considering the fact that fuel now accounts for over 40 percent of airline operating costs, the savings could be significant.

It should be made clear, however, that although ASDAR equipped aircraft can provide a significant improvement to the present data base, it is not the total solution. No single system can provide all the necessary data and at best a composite observing system is required. ASDAR can however play a very important role in the global observing system. Because of this potential a major effort is presently being mounted by the World Meteorological Organization to obtain International support for ASDAR. If this support is forthcoming and there are indications that it will be, then ASDAR can provide a major new data source for global meteorology within 5 years.

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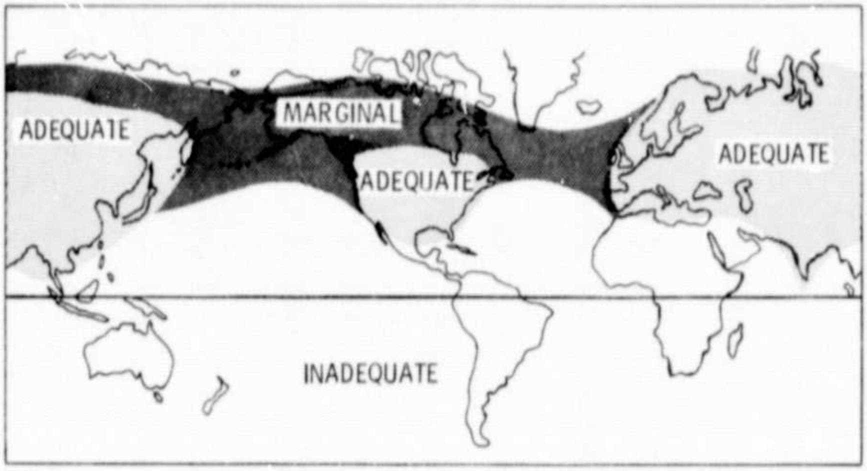

Figure 1. - Current availability of upper air data.

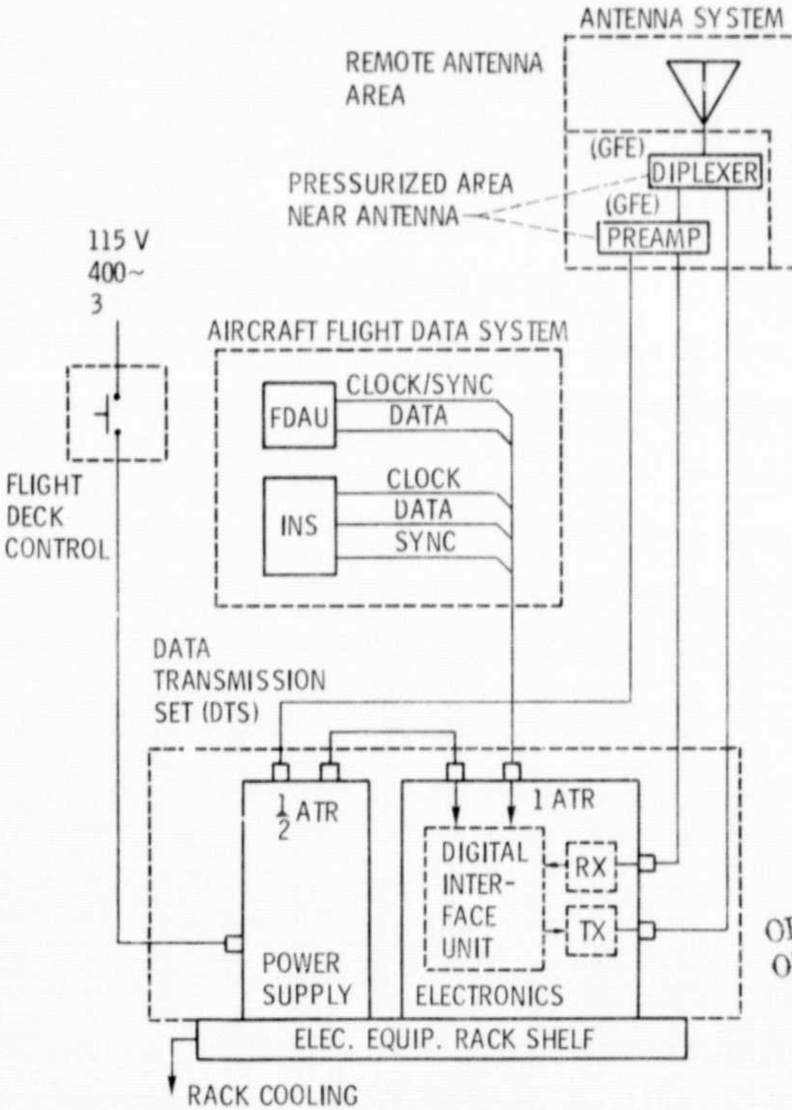

Figure 2. - Block diagram of Aircraft to Satellite Data Relay (ASDAR) system.

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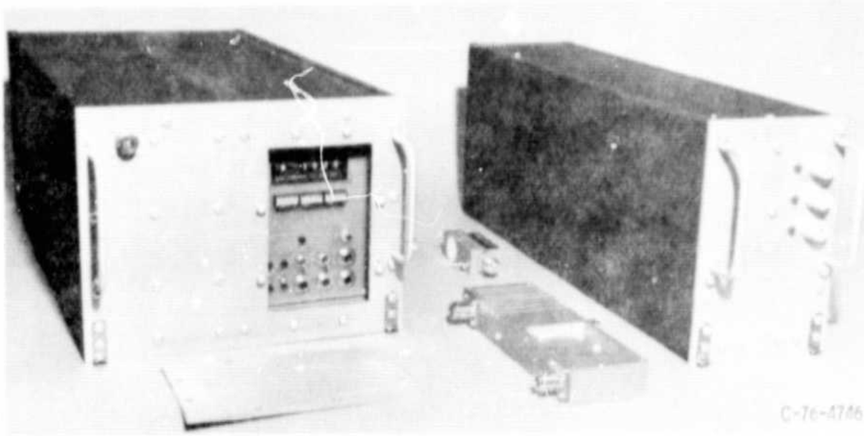

Figure 3. - Complete ASDAR system (except for antenna); transmitter, receiver and digital interface unit in box on left - power supply on right - diplexer in foreground and preamplifier in background.

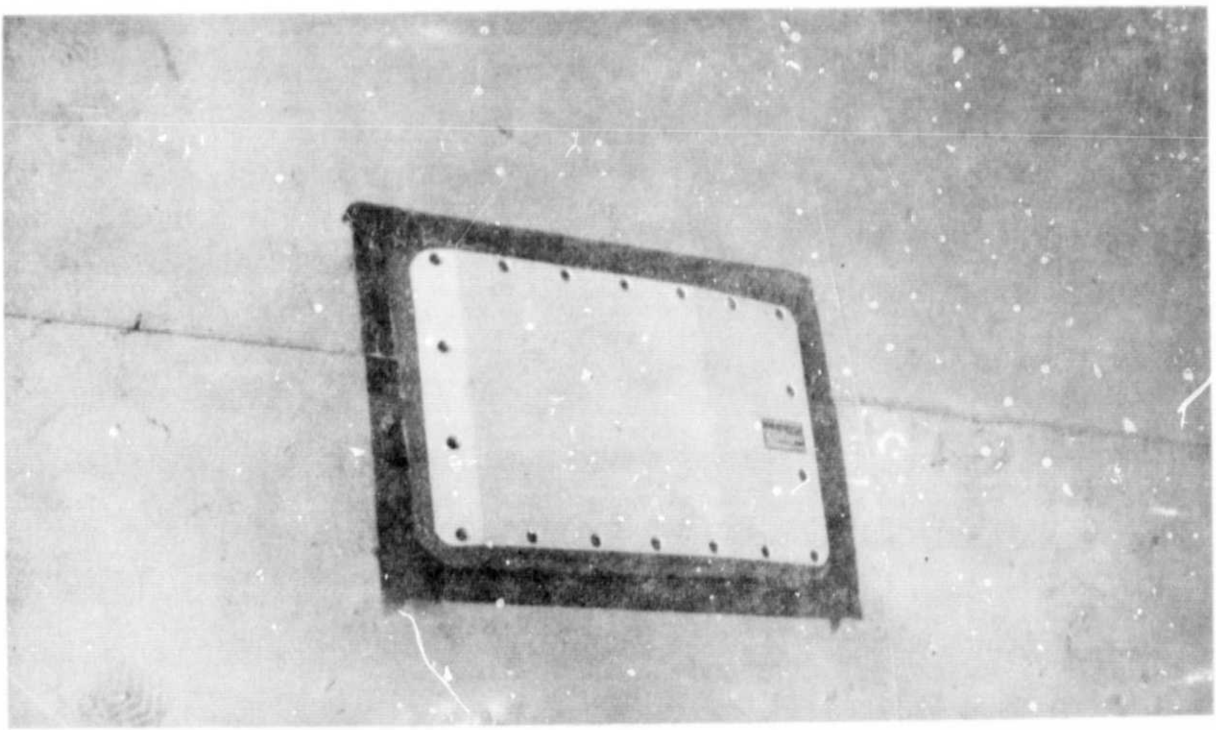

Figure 4. - Prototype ASDAR Coplanar Stripline transmit-receive antenna mounted on Pan American B-747 aircraft.

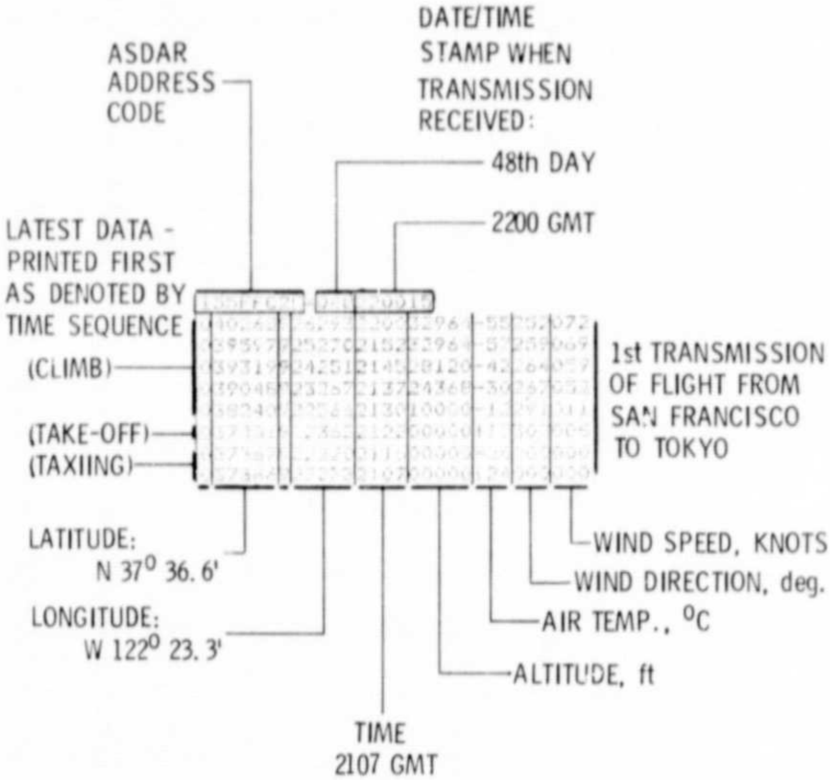

Figure 5. - ASDAR printout obtained, via satellite relay, from National Satellite Service.

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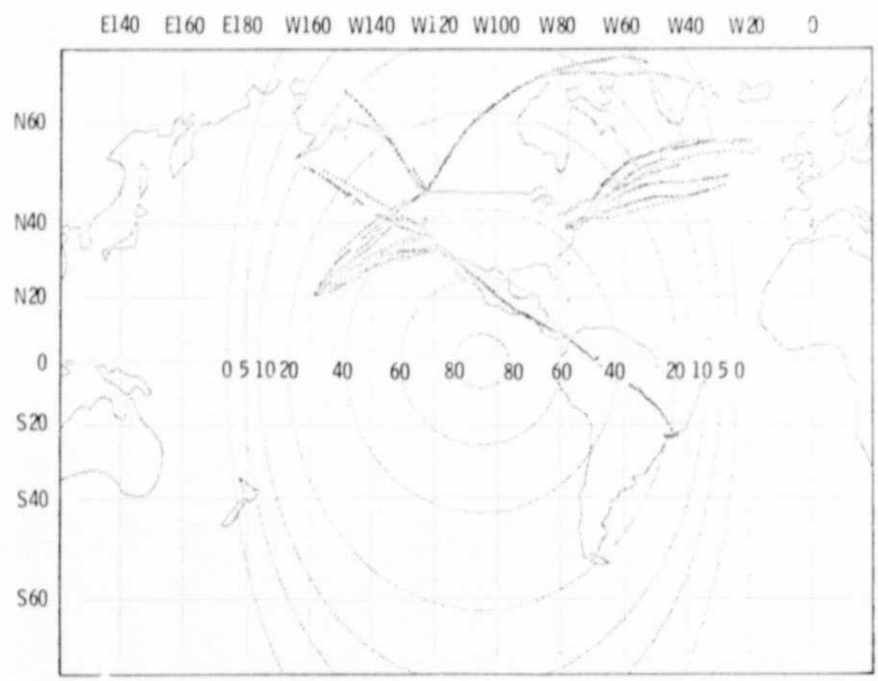

Figure 6. - ASDAR data record points with contours of constant elevation to the receive satellite.