NASA Technical Memorandum 78992

(NASA-TM-78992) AN AIRBORNE METEOROLOGICAL DATA COLLECTION SYSTEM USING SATELLITE RELAY (ASDAR) (NASA) 17 p HC A02/MF A01 CSCL 17B

N78-33283

Unclas

G3/32 33636

AN AIRBORNE METEOROLOGICAL DATA COLLECTION SYSTEM USING SATELLITE RELAY (ASDAR)

James W. Bagwell and Bruce G. Lindow
Lewis Research Center
Cleveland, Ohio

TECHNICAL PAPER to be presented at the
International Telemetering Conference
sponsored by the Instrument Society of America
Los Angeles, California, November 14-16, 1978

AN AIRBORNE METEOROLOGICAL DATA COLLECTION

SYSTEM USING SATELLITE RELAY (ASDAR)

ORIGINAL PAGE IS OF POOR QUALITY

by James W. Bagwell and Bruce G. Lindow

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

INTRODUCTION

The Aircraft to Satellite Data Relay (ASDAR) project was begun in 1975 as a joint NASA/NOAA program to provide an improved source of meteorological data for weather forecasting. The initiative for starting the project came from a recognition that much of our weather originates in the data sparse areas of the tropics and Southern Hemisphere. It was further recognized that these areas are frequently crossed by many of the modern, wide-body jet aircraft of the B-747, DC-10 type. These aircraft contain navigation and data systems capable of providing the following data: latitude, longitude, altitude, wind speed, wind direction, and outside air temperature. The ASDAR system consists of a data acquisition and control unit to acquire, store, and format this data; a transmitter to relay the formatted data via satellite to the ground; and a clock to time the data sampling and transmission periods. In cooperation with the National Oceanic and Atmospheric Administration (NOAA) the data is relayed to the ground via their Geostationary Operational Environmental Satellite (GOES) series and then to the National Meteorological Center (NMC) to aid in weather forecasting.

SYSTEM DESCRIPTION

Data Sources

The B-747 aircraft used in commercial airline service uses an Inertial Navigation System (INS) and a Flight Data Acquisition Unit (FDAU) as part of its complement of avionics equipment. These two units serve as sources of the data necessary to provide the wind speed and direction, and static outside air temperature at a specific latitude, longitude and altitude. The INS system provides the latitude, longitude, wind direction, and wind speed as serial, BCD data. The FDAU system provides altitude and outside static air temperature in the form of PCM serial data.

Data Format

These data are the same as are normally manually reported by airline pilots in the form of aircraft reports (AIREP's). The ASDAR reports are formatted in a manner similar to these reports. As a result of the onboard formatting prior to transmission, the message as received on the ground requires little processing to be suitable for insertion onto the Global Telecommunications System (GTS) and, subsequently, into the weather data base. A sample formatted message is shown in Figure 1 as it is received and printed on a ground terminal.

Major System Elements

The major elements of the ASDAR system are shown in Figure 2. Clockwise they are the electronics unit, the antenna, and the power supply. These are interconnected as shown in Figure 3. As described previously, data from the aircraft INS and FDAU are fed into the Data Acquisition and Control Unit (DACU). A battery powered clock was developed and is included in the electronics unit along with the DACU. The clock output is used by the microprocessor based controller to determine the data sampling times and transmission times. In normal operations, eight complete sets of data are acquired over a one hour period and transmitted to the satellite at a precise time each hour. The DACU provides all the necessary scaling to the data and stores it in International Alphabet No. 5 in 8 bit ASC II. At the appropriate time each hour, the DACU turns the transmitter on and delivers a Manchester bi-phase data signal to phase modulate its carrier.

The transmitter is an 80 W device designed for intermittent operation within the electronics unit. The transmitter operates at a nominal 402 MHz and feeds a Coplanar Stripline antenna mounted on the top of the B-747 aircraft.

Physical Layout

The DACU, clock, and transmitter are all packaged in the electronics unit which conforms to a 1 ATR (Air Transport Rating) package whose dimensions are 26 cm wide by 19.69 cm high by 50.17 cm long with a weight of 13.27 kg. The system is powered by a separate power supply contained in a ½ ATR package whose dimensions are 12.7 cm wide by 19.69 cm high by 50.17 cm long with a weight of 5.58 kg. These two units are mounted in the forward electronics rack of the B-747 aircraft as shown in Figure 4. The RF cable is routed, as shown, to the top of the aircraft where it is connected to the antenna mounted on the outside skin of the aircraft. The total system weight including mounting hardware, cables, and antenna is 30.19 kg.

DETAILED FUNCTIONAL DESCRIPTION

Data Acquisition and Control Unit (DACU)

Because the DACU contains a microprocessor, the operating features are readily changed by reprogramming. The operating characteristics described herein reflect the present programming decisions, realizing that changes may be made in the future. As shown in Figure 5, the DACU consists of three major circuit boards: the I/O board, the CPU board, and the front control panel. The function of each will be described in the following paragraphs.

The front control panel of the DACU contains a number of switches that can be used to select various options in the programming of the microprocessor. It also contains five LED indicators that give a visual indication of the status of the DACU. For use with external equipment, there are 4 jacks that can also be used to diagnose the operation of the DACU. Figure 6 shows the front control panel and identifies its functions.

The DACU operates on a specific time schedule, acquiring data and transmitting the data to the satellite at times that are selected by thumbwheel switches on the DACU front panel. Many ASDAR units will share a single RF channel, hence each unit is assigned a specific time slot for data transmission. When a unit is to transmit a data message, there is a predetermined sequence of events that must be performed by the DACU. For a single data point, the overhead required as a preamble to the data transmission would be longer than the data part of the message. Rather than transmitting many short data messages, the DACU of the ASDAR units stores data sets in memory and then transmit blocks of stored data in order to make more efficient use of the RF channel. As a compromise, the ASDAR units always transmit eight sets of data during each transmission sequence. Therefore, if a unit is set to transmit data once every hour, then the eight sets of data would be recorded at 7.5 min intervals.

As mentioned earlier, each ASDAR unit is assigned a specific time slot for its transmission. This requires that the DACU have access to a clock. The aircraft systems do not have a clock that is accurate enough to time the transmissions, so the ASDAR package must have its own clock, therefore, a clock was integrated into the electronics unit.

When the DACU determines it is time to transmit data, the DACU must turn on the ASDAR transmitter and then send the following sequence:
(1) 5 secs of unmodulated carrier
(2) 2.5 secs of alternating 1's and 0's
(3) 15 bit MLS
(4) 31 bit unit address
(5) 8 sets of data
(6) 3 end of transmission codes, 31 bits each

After the end of the message, the DACU turns off the transmitter. The total message length is about 25 secs when the data is transmitted as an 8 bit ASC II coded message.

The data acquired from the aircraft systems for each reading is as follows:
(1) Present position, latitude
(2) Present position, longitude
(3) Altitude
(4) Outside static air temperature
(5) Wind direction
(6) Wind speed
In addition to these parameters, the time of the data reading, in hours and minutes, is also recorded. The latitude, longitude, wind direction, and wind speed are obtained from the aircraft INS. The altitude and outside static air temperature are obtained from the aircraft FDAU system.

ORIGINAL PAGE IS
OF POOR QUALITY

Front panel switches. - The front panel of the DACU contains a number of switches for control of the DACU. Figure 6 shows the front panel.

The thumbwheel switch labeled PER HOUR is used to select the number of transmissions per hour. This switch is labeled with 0, 1, 2, 4, 8, and 16. The position labeled 0 is a special setting that is used for diagnosis of the DACU and for installed system testing and is not for normal operation. The switch positions labeled 1, 2, 4, and 8 could be used for normal operation if so desired, but it is anticipated that most ASDAR units will use a setting of 1 transmission per hour. The switch position of 16 transmissions per hour must be used with caution, and should not be used for normal operation. As mentioned earlier, the DACU always stores 8 sets of data for each transmission. When the transmission rate is set for 1 transmission per hour, the data is recorded at 7.5 minute intervals. When the transmission is set at 16 transmission per hour, the data is recorded at 28 second intervals. The front panel data printout takes about 41 secs, and an 8 bit ASC II data transmission takes about 29 secs. This means that for 16 transmissions per hour, the first data reading is taken before the previous transmission has finished, which can cause some rearrangement of the data readings. When the transmission rate is set at 0, the DACU is in a special test mode. Data is recorded at approximately 9 second intervals and dumped out to the front panel jack labeled TTY. This mode of operation is quite useful for checking problems with the INS or FDAU systems. In addition, when the DACU is reset, in this mode, the transmitter is turned on for a short message (about 10 secs) to allow easy and rapid test of the RF system.

The other thumbwheel switches are labeled MIN and SEC, which correspond to the starting time of the transmission, in minutes and seconds, respectively. If the number of transmissions is set at a number greater than one, then the time of one of the multiple transmission is entered on these switches. The DACU will calculate the other transmission times at equally spaced intervals.

The set of rocker switches labeled ADDRESS are used to enter a unique 21 bit address into the ASDAR unit. These switches are used to enter the most significant 21 bits of the 31 bit BCH address. The DACU will calculate the 10 extra check bits that make up the 31 bit address. If a switch is ON, then the corresponding bit is a binary 1, and if a switch is OFF, then the corresponding bit is a binary 0. When an address is assigned to a unit, it will usually be given as an 8 digit hex number by the National Environmental Satellite Service (NESS). The 21 bit address to be entered on the front panel is contained in the leftmost bits of the hex number. Since an 8 digit hex number comprises 32 bits, the extra bit, by NESS convention, is the least significant bit of the rightmost digit.

The toggle switch labeled ALT is used to enable or disable transmissions below a certain preprogrammed wind speed. This is done to allow for transmissions to be inhibited while the aircraft is on the ground. This condition is indirectly indicated by the wind speed which is caused to read zero below 160 knots air speed of the aircraft. At the present time, the cutoff wind speed is programmed at 0 knots. The DACU looks at the last wind speed received from the INS system for comparison with the programmed cut-off value. If the ALT switch is set (up position), then if a transmission is scheduled to occur at a time when the wind speed is less than the programmed wind speed, the DACU will skip the transmission sequence. Also, if the switch is set and the DACU is not receiving good data from the INS system, then the transmission will be skipped. If the switch is reset (down position), then the DACU will always transmit, regardless of the wind speed.

The switch labeled DADS/CADS (INT on early ASDAR units) is used to select the type of FDAU data that the DACU is to expect. For most DC-10's, the switch should be in the up position (DADS), and for most B-747's, the switch should be in the down position (CADS). This switch just directs the microprocessor in its interpretion of the FDAU output. When the switch is set to the CADS position, the microprocessor converts the incoming FDAU data to a DADS format before it stores the data for transmission.

The remaining switch on the front panel is labeled RESET. By depressing this switch, the microprocessor is forced to execute the initialization coding, the same as if a power-up condition just occurred. This switch is particularly important when working with the DACU. The only time that the DACU examines the front panel switch settings is when the power-up restart coding is executed. Therefore, whenever any of the front panel switches are changed, the RESET switch must be depressed to force the microprocessor to examine the front panel switches. It should also be pointed out that the internal clock of the DACU will be reset when the RESET button is depressed, and hence a new time update must be received from the clock subsystem to set the DACU clock.

Front panel indicators. - Also shown in Figure 6 are the five LED indicators on the DACU front panel. These LED's are provided to give a visual indication of the ASDAR system status. Three of the LED's are controlled by the microprocessor and the other two are hardware controlled by the DACU.

The LED labeled +5 V is connected across the +5 V power of the DACU and should be illuminated whenever the power is on to the DACU. The LED labeled RCVR is connected to the clock indicator signal. The LED is driven by logic on the I/O board, but is independent of the microprocessor operation. Therefore, when the clock is on the RCVR LED should be illuminated. This LED can also be illuminated when the DEMO jack is used, but this will be discussed later.

The LED's labeled INS, FDAU, and TIME are controlled by the microprocessor. The LED labeled TIME will be illuminated whenever the DACU is receiving valid time updates from the clock, or from the front panel. When a valid time update is received, the LED will be turned on and left on until a time update is not received as expected. That is, when a time update is received, the LED will remain on for about 2 secs at a minimum, unless the clock malfunctions.

The LED labeled INS is used to display the status of the data being received from the aircraft INS. The LED will be turned on when one of the desired parameters is received from the INS. If a period of about 5 secs elapses without receiving a parameter from the INS, then the LED will be turned off.

The LED labeled FDAU is used to display the status of the FDAU system. The FDAU clock received by the DACU is 16 times the data rate. Every 4096 data bits the FDAU clock contains a special sync pulse, and if the DACU has counted 4096 data bits since the last sync pulse, then the FDAU LED will be turned on. This LED is not turned off on a timed basis like the INS LED. If the FDAU clock is stopped while the FDAU LED is on, the LED will stay on.

Front panel jacks. - The front panel of the DACU contains four jacks that can be used to help diagnose problems with the DACU. Three of the jacks contain output information from the microprocessor, and one jack is used to replace the role of the ASDAR clock subsystem with an external piece of equipment.

The jack labeled DEMOD is used to simulate the clock subsystem input to the DACU. When a simulator is plugged into the DEMOD jack, the RCVR LED is forced on, and the clock and data lines are switched from the clock subsystem to the front panel inputs. The lock indicator status line into the microprocessor is forced to a locked indication. The microprocessor cannot detect whether the clock input is from the ASDAR clock or from the front panel DEMOD jack. The clock and data inputs to the jack must be +5 V CMOS compatible, and the data must be bi-phase encoded data.

The jack labeled MOD contains the same data that is sent to the transmitter by the DACU. The signal is TTL logic compatible signal with Manchester bi-phase encoded data. By proper wiring of the plug for this jack, the transmitter output can be inhibited, and the transmitter data can be forced to a zero value since the data appearing at the jack is not buffered. The transmitter cannot be forced on through this jack, it can only be inhibited from turning on. The data output to the transmitter is a tri-level code, with logic levels of 0, 2.5, and 5 V nominally. When the transmitter is not enabled, and when the DACU is sending unmoduled carrier, the data output will be at 2.5 V. When the DACU is sending data, the logic level at the jack will be either 0 or 5 V. The drive circuit uses an open collector TTL gate with a pull-up resistor, so that the data output of the DACU can shorted to ground at this jack without hurting the DACU circuits.

The jack labeled TIME is a diagnostic output that can be used to indirectly drive a teletype. The jack output is a CMOS compatible signal with a 100 bits per second data rate. The data code is an NRZ code, rather than bi-phase like the MOD jack. The data format is an 11 bit character format, the same as that required by a teletype. To drive a teletype, the data rate must be changed to 110 bits per second, and the logic level must be converted to a dc-current loop type signal. A typical output from this jack is as follows:

P=HH:MM:SS* R=MM:SS T=MM:SS

where the value following the P= is the current setting of the DACU internal clock, in hours, minutes and seconds. The asterisk following the time is present if the microprocessor has not received a valid time update, in which case the current time is a count from the last power-up restart of the microprocessor. If the DACU has received a valid time update, the asterisk will not be present. The number following the R= is the time until the next data reading, in minutes and seconds. The number following the T= is the time until the next transmission, in minutes and seconds. The output on this jack is always present as long as the microprocessor is running.

The jack labeled TTY contains basically the same data that is sent to the transmitter each transmission. The data is made a little more readable by inserting spaces and prefixes, but the data is the same as the data for the transmitter. The logic level on this jack is the same as for the TIME jack, and the data character format is also an 11 bit async character code. The first line contains the unit address in binary. The leftmost bit is the first bit

transmitted. The data lines contain one data reading on each line. The parameters are printed in the following order:
(1) latitude, in degrees, minutes and tenths of minutes
(2) longitude, in degrees, minutes and tenths of minutes
(3) time of this reading, in hours and minutes
(4) altitude, in feet
(5) outside static air temperature, in degrees celsius
(6) wind direction, in degrees
(7) wind speed in knots
If the transmission rate is set for 0 transmissions per hour, then the output on this jack contains only the data lines. The output will be a current print-out of the data buffer approximately every 9 secs. This special output can be used to examine the INS and FDAU data on an almost continuous basis.

CPU board description. - The CPU board contains the 8 bit microprocessor, 512 bytes of RAM storage, 4096 bytes of PROM storage, and other miscellaneous circuits. The PROM storage is composed of eight 512 byte fusible link PROM's. These PROM's were selected because of their ability to operate from a single +5 V supply. The remainder of the circuitry on the board comprises the buffering of the microprocessor signal lines, and clock circuits. The clock circuits operate from a 4 MHz crystal oscillator. This crystal is used to generate the two-phase clocks required by the microprocessor, and to generate a 1600 Hz signal that is used on the I/O board. The microprocessor is operated at its maximum speed of one MHz.

I/O board description. - The I/O board contains all of the special I/O interfacing required by the DACU. All of the connections to the microprocessor are made through two peripheral interface adapter (PIA) chips. With the exception of the two PIA's, one chip for driving the transmitter, and the optical isolators, the remainder of the circuitry on the I/O board is CMOS. The interface to the INS generates 8 bit parallel data. The other systems (FDAU, clock, transmitter, and front panel) all use serial inputs and outputs.

In addition to the data interfaces, the I/O board also contains a low voltage detection circuit. This circuit is designed to give the microprocessor a reset signal if the +5 V supply voltage falls below about 4.75 V. This was done to prevent any low voltage spikes from leaving parts of the circuitry in an indeterminate state.

Clock Subsystem

The clock subsystem consists of a single circuit board and a 7 amp-hour Ni-Cad battery as shown in Figure 7. The clock circuitry was developed using an 8 bit CMOS microprocessor and random access memory only. A 1 MHz temperature compensated crystal oscillator was selected as the frequency standard. It has a yearly aging rate of 5×10^{-7} parts per year and a temperature stability of $\pm2\times10^{-7}$ over 0° to 50° C. The clock circuitry consumes 60 mW of power of which 40 mW is consumed by the crystal oscillator. The battery, operating at 12 V, can keep the clock running for approximately 30 days; enough time for the clock to be set prior to shipping and then shipped as a part of an ASDAR system to an airline and installed.

A battery charging circuit is also included on the circuit card to permit the 28 VDC available from the power supply to charge the battery when aircraft power is on. A full battery charge is obtained in about 24 h of time with aircraft power on.

As mentioned above, only RAM memory is used in the clock circuitry. Thus, to cause the clock to operate, both the microprocessor program and the correct time must be loaded into the memory upon clock startup. This is effectively accomplished using a separate set-time unit which connects through a connector behind the hinged cover on the front panel of the electronics unit. An enable button is also provided to ensure glitch-free connection to the clock when setting the time. When the switch is depressed, an adjacent LED indicator tells whether the clock is running or not by displaying the reset status of the microprocessor.

Although the initial driver for the RAM only clock design was the unavailability of low power CMOS proms, this was later found to be an asset since it is desirable to have the clock stop positively upon a power interruption rather than resume operation with an erroneous time. This is a natural result of having the microprocessor program solely in volitile RAM. Furthermore, the complexity of the external set-time unit is not significantly increased by requiring it to load the program in addition to the correct time.

Transmitter

The transmitter consists of a single unit enclosed in a machined aluminum case as shown in Figure 8. Its dimensions are 13.97 cm wide, by 5.33 cm high, by 27.94 cm long, and it weighs 3.118 kg. The output frequency of the transmitter is determined by a plug in crystal controlled oscillator contained in a proportionally controlled oven operating at 80° C. The modulating data input and control signal are provided by the DACU as described previously.

The output of the transmitter is nominally 80 W and is fed from the transmitter to a connector on the front panel of the ASDAR system. At this power level, the transmitter is designed only for the typical intermittent operation as is experienced in the ASDAR application.

The frequency stability of the transmitter is specificed at 1×10^{-6} per year, which should assure successful performance for about one year given the GOES channel bandwidth constraints. This characteristic will be discussed more fully in the Design Considerations section below.

Power Supply

The power supply is totally contained in a separate package, $\frac{1}{2}$ ATR in size. The power supply takes raw, unfiltered 115 V, 3 phase, 400 cycle power from the aircraft, filters and conditions it down to 5 V and 28 V DC. While transmitting, the power drawn from the aircraft 3-phase bus is 604 VA. At all other times, the power is 104 VA. All parts of the electronics unit are fed by the 5 V supply except the transmitter and clock charging circuitry.

Each output, 5 V and 28 V, are separately fused and have red LED indicators to indicate operation when lit. The 5 V supply nominally provides 2 A. The 28 V supply nominally provides 11.5 A when transmitting and 0.6 A when not transmitting. Internal filtering in the power supply is adequate to provide noise-free power in accordance with the conditions outlined in the ARINC specifications. Internal protection is also provided for over current, over voltage, and under voltage.

Antenna

The antenna, shown in Figure 2, is a Coplanar Stripline type, 20 cm wide, by 40 cm long, by 1.9 cm high, contoured to fit the curvature of the aircraft fuselage. The following specifications are being met for production antenna's:

Frequency: 402 MHz nominal
Gain: 1.5 dbic
Axial ratio: <5 db

Although the intent of this antenna when developed was to both transmit at 402 MHz and receive at 468 MHz, its fabrication for production ASDAR systems excludes the receive capability and favors transmit performance.

DESIGN CONSIDERATIONS

Interface Options

After some preliminary investigations, it was determined that not all commercial aircraft of the newer wide-body type carry the same avionics equipment. For the most part, a particular type such as the B-747 will be the same from aircraft to aircraft, but differences are still possible particularly when dealing with foreign airlines. Since the objectives of the initial ASDAR program were to equip a limited number of aircraft to provide data through the First Global Garp Experiment (FGGE), which has a duration of one year beginning in December, 1978, the B-747 aircraft was selected for initial interfacing.

The particular interface standards for which the ASDAR has been designed are ARINC 561-11 for the INS, and ARINC 573-7 for the FDAU. This decision has permitted a rather broad choice of airlines on the basis of most favorable routes. In fact, it has been possible to use a standard installation kit including drawings and hardware for all B-747's to date.

In the present prototype ASDAR systems, the interface to the INS and FDAU are constituted primarily in hardware, and modifications to adapt to different types of avionics equipment is difficult. As noted earlier, a Digital Air Data System (DADS)/Central Air Data System (CADS) option is provided so that some compatibility is afforded for DC-10's. This option will provide compatibility for the FDAU interface, but the DC-10 must also carry an INS system if full compatibility is to be realized, which is not necessarily the case. Numerous aircraft including DC-10's are now carrying, or plan to carry, OMEGA navigation systems. Although the essential data is presumably present, the interface to such a system would be different. As a further complication, some aircraft have been found which have slight modifications to their avionics equipment in either hardware or software.

In light of the above findings, it is recommended that future designs of ASDAR systems consider options in both hardware and firmware, which will facilitate easy adaptation to avionics equipment of different types. Physical modularity of functions may be a way of accommodating this requirement.

Environment

The ASDAR system was designed to survive and operate in the below deck electronic equipment area of commercial aircraft; the only external part of significance being the antenna mounted on top of the fuselage. The environment of the equipment areas of these aircraft are conditioned by cabin exhaust air so extremes in temperature should not be experienced by the equipment while the aircraft is operating. Nevertheless, attempts were made to adhere to RTCA-DO160 specifications for equipment on this class of aircraft. Thermal, vibration, humidity, and EMI tests were conducted.

The thermal specification in this case is -55° to +85° C. Due to constraints imposed by the transmitter, the system was tested from -40° to +70° C only. It was subsequently determined that the PROM's in the DACU were experiencing trouble at temperatures well above this lower limit. This was subsequently traced to thermal sensitivity in the power switching circuitry on the PROM chips. To rectify this problem, the power switching feature of the PROMS was bypassed, thus avoiding the use of the temperature sensitive circuitry; but, thereby, increasing the power consumption.

As might be expected, the levels of vibration encountered on modern commercial jet aircraft are relatively low. As a result, testing to the required levels of both sine, random, and shock were generally uneventful. Only one anomaly was noted while the system was being subjected to random vibration. The transmitter frequency was observed to shift. This was traced to a poorly secured crystal oscillator within the transmitter oven assembly. A bracket was added to eliminate the problem.

No anomalies worth noting were experienced during humidity and EMI testing of the ASDAR system in the laboratory chambers. Since this system was to fly on aircraft in commercial passenger service, extensive examination and testing were required prior to the necessary Federal Aviation Administration (FAA) certication. Since the certification process would have to include a flight test, a contract for the complete flight certification was given to Pan American Airways. The necessary testing and flight were successfully performed on February 4, 1977. A formal "Flight Test Report" (Ref. 1) has been published covering the flight test and results.

From another perspective, the environment includes a time factor which may be of importance under certain circumstances, which will be described later. Due, in part, to the desire of airlines to maximize the revenue from expensive, modern jet aircraft, a typical day's flying time may total 12 to 16 h. These flights are interspersed with periods of off-time where neither power nor environmental air conditioning are supplied to the aircraft and its equipment. Thus, susceptible electronic equipment may be affected by these conditions.

The environmental condition yet to be addressed is that affecting the antenna. Of all the ASDAR equipment, it is exposed to the most severe environment. This includes the extremes of temperature, humidity and physical abuse. Experiences during the development of the ASDAR antenna have revealed instances of moisture leaks and surface erosion. The moisture leaking condition was corrected early in the program. Surface erosion as observed on the ASDAR antenna is considered normal for equipment so located on the aircraft. As a result, periodic replacement (about every two years) of protective surface coatings may be required.

Of potentially greater concern is whether such an attachment to the outer skin of the aircraft will tend to build up ice. Should this happen, sudden breaking off of ice particles could cause damage to aircraft parts in flight. This is of particular concern with an antenna mounted ahead of the top engine of a DC-10, where ice ingestion by the engine could cause significant damage. Although no ice formation has been noted on the present B-747 installation, no implications can be drawn with respect to performance on a DC-10 and, therefore, qualification tests must be repeated on the DC-10 prior to certification.

Transmitter Stability

As noted earlier, the NESS specification for transmitter stability is 1×10^{-6} per year. At 400 MHz this would result in a possible frequency shift of $\pm$400 Hz. This is enough to take a transmission to the band-edge of a GOES channel. Therefore, under minimal specified performance, a transmitter would stay in band for about one year.

A further complication to continued successful performance of such a transmitter results from using it in a mobile application as is the case when used on an aircraft. In this case doppler shift phenomena enters in and may either add to or reduce the frequency shift due to other factors. In the case of ASDAR equiped aircraft operating with a GOES satellite, a maximum doppler shift of approximately 360 Hz is possible when radially approaching or departing from the satellite at the horizon. When comparing the combined effects on transmitter frequency, it becomes apparent that far better frequency stability with time is required if the effects of doppler shift are not going to take the transmitter out of band.

There are many possible approaches to solving this problem, such as increasing the channel width to allow for more frequency shift. But, considering only those options which involve the mobile transmitting platform, the range of possibilities becomes limited. Some possible approaches are:
(a) Synthesize the transmit frequency from a stable source relayed via the satellite from the ground.
(b) Provide a ground command capability to allow remote frequency adjustment in flight.
(c) Occasionally adjust the frequency using test equipment by taking the system out of service on the ground.
(d) Provide a sufficiently stable transmitter such that frequency shifts other than the result of doppler are insignificant.
(e) Determine the effect of doppler and adjust the transmit frequency accordingly.
(f) Some combination of the above.
Upon examination, each of these techniques has its disadvantages. (a) and (b) require the presence of a receiver as part of the system. (a) would further require the result of (e) to avoid doppler affecting the stable source from the satellite. (d) would be a preferable method if it could be done cost effectively. If a receiver is included its cost could be traded against that of a stable transmitter.

It would be desirable to have a transmitter whose output frequency stability with respect to all influences was not worse than $1x10^{-7}$ parts per year. This may not be too difficult to reach if advantage is taken of the actual environment which the oscillator sees. First, the intermittent characteristics of the power source indicates that an ovenized oscillator operating at 80° C is not desirable. This would cause daily thermal cycles of the order of $\Delta 60°$ C. Secondly, the actual operating environment is not likely to exceed approximately 20° C for any period of time and be more likely to fall below. Therefore, a temperature compensated crystal oscillator operating within an oven whose operating temperature is 25° C would result in better long term stability. The oven would still operate only intermittently but, most importantly, it would maintain the oscillator temperature in flight where the environment is going to be less than 20° C.

Timing Sources

Early in the development of the ASDAR system, a receiver was included to allow the use of satellite time for controlling data acquisition and transmission periods. After demonstrating its successful performance during the first six months after flight certification in February, 1977, it was learned that coded timing was only going to be provided on the US GOES, not the European or Japanese ones. Without's a consistent, world-wide timing source, the receiver for timing purposes became of limited value. Thus, after six mos of successful performance, the decision was made to replace the receiver with a presettable clock with backup battery. The operational philosophy to be followed was one of providing sufficient battery capacity to allow setting the clock prior to shipment to an airline and battery recharging from the aircraft power.

The clock subsystem was developed and certified by the FAA for inclusion in the ASDAR system on December 13, 1977. The concept has been shown to be operationally feasible and, although presently allowing a 2 min period per transmission, appears to be capable of sufficient stability to allow for one min transmission periods. These assumptions are based on resetting the clock after one year's operation.

After almost a year's experience using the clock in the ASDAR system, there is some concern that this concept carried into an operational ASDAR system involving hundreds of units in the field could prove awkward and logistically undesirable. Specific locations would have to be provided with time-setting equipment. Spare, back-up, systems could not be stored in a ready-to-install condition without periodically applying power to recharge the clock battery.

To overcome these, and possible other specific objections, a variation to the clock concept is being considered for operational systems, post FGGE, i.e. after 1979. This redesigned system would include both a receiver and a battery powered clock. In concept, the receiver would automatically set the clock and enable the system to operate when the aircraft is within view of the two GOES satellites, approximately two-thirds of the globe. The battery capacity would be sufficient to sustain clock operation for periods up to 5 days without aircraft power. This should be enough to allow for normal maintenance periods and weekend layovers. Should the clock stop operating in an area out of sight of a GOES satellite, most airline routes should bring it back in view within a week.

Should an operational ASDAR system come about, an improved timing system as described here should be considered. A factor in determining the nature and accuracy of the system timing is the channel packing density desired to support the number of ASDAR equipped aircraft likely to be flying in the 1980's.

PERFORMANCE

Apart from periods of time where the ASDAR system was being redesigned or recertified, the performance since February, 1977, has been exceptional for a prototype system in an experimental program. ASDAR is a joint project between NASA and NOAA to provide airborne weather data collection platforms for the FGGE experiment beginning in December, 1978. Since NASA's responsibility is limited to the design, development, installation, and operation of the ASDAR system as a data collection and transmission system, its performance will be addressed principally in this context and not with respect to the quality and value of the data. It is obvious from the preceding paragraphs that some modifications and improvements have already been made to the ASDAR system. Early in the project numerous changes were made to either correct errors in understanding the formats of the data from the aircraft equipment or modify the processing format of the data collected. These changes were made much easier due to the microprocessor in the DACU. In the last year and a half, modifications were made to accommodate factors apart from the ASDAR system, such as the lack of satellite time or to improve operational reliability.

The ASDAR reliably and consistently acquires the aircraft data. Data transmissions are consistently good and free of errors within the footprint of the satellite, which is really horizon-to-horizon. Figure 9 shows data from an aircraft carrying an ASDAR system over a three month period. Many of the flights overlap in their tracks. As can be seen, data coverage sometimes exceeds the horizon.

Beginning in December, 1978, there will be 17 ASDAR systems flying on numerous international airlines. Having completed their prime objective by the end of 1979, it is anticipated that these 17 systems will continue to be flown and will make up the beginning of an operational ASDAR fleet. As explained earlier, much has been learned during the development of the ASDAR system. As a result, it has been concluded that an ASDAR system, to be successful in an operational environment, must be repackaged and somewhat modified in design if it is to be cost effective to purchase, operate, and maintain.

To date, all indications from NOAA are that ASDAR is a valuable addition to their array of weather data collection sources. The data is sufficiently accurate when compared with other sources of data, that it is among the highest weighted data in their weather data base.

CONCLUDING REMARKS

In the conduct of the joint NASA/NOAA project to collect upper atmosphere meteorological data an airborne data collection and transmission platform has been successfully developed and has performed well as one element of a complex system consisting of a fleet of commercial aircraft, the ASDAR system, the GOES satellite family, the NESS, and the NMC. The contribution of NASA to this project has combined the modern technologies of avionics, microprocessors, antennas and satellite communications for an effective addition to the techniques used in monitoring global weather. Having demonstrated the feasibility of this technique it is anticipated that ASDAR will grow into a world-wide operational system.

REFERENCE

1. Domino, Edward J.; Lovell, Robert R.; Conroy, Martin J.; and Culp, David H.: ASDAR (Aircraft to Satellite Data Relay) Flight Test Report. NASA TM-73744.

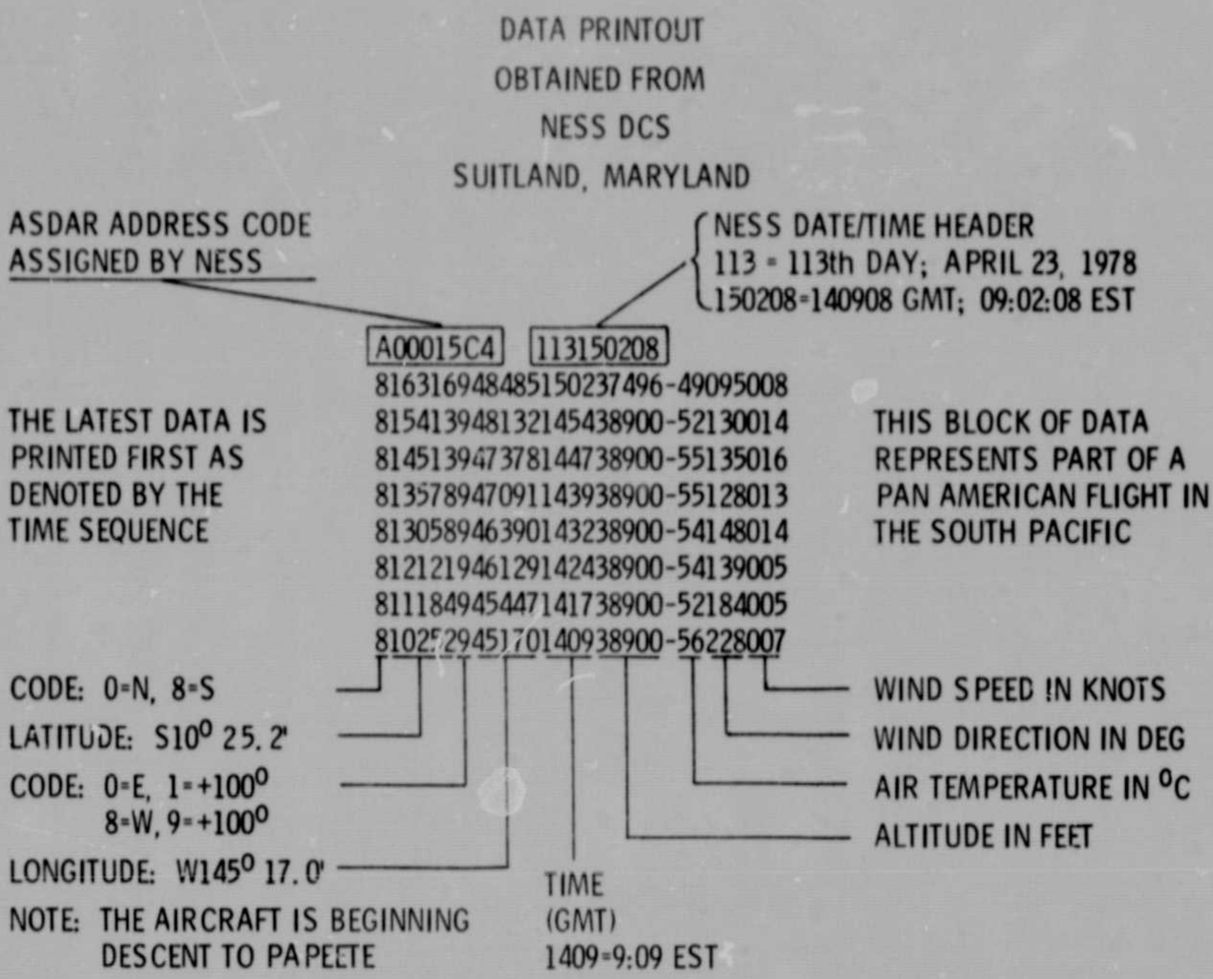


Figure 1.

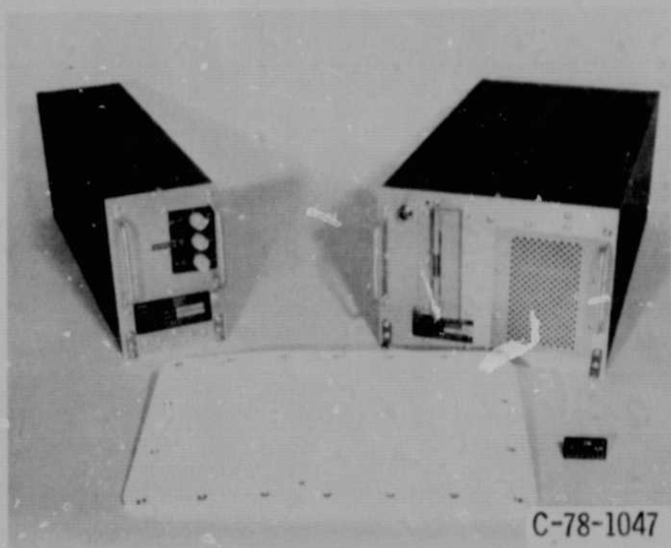
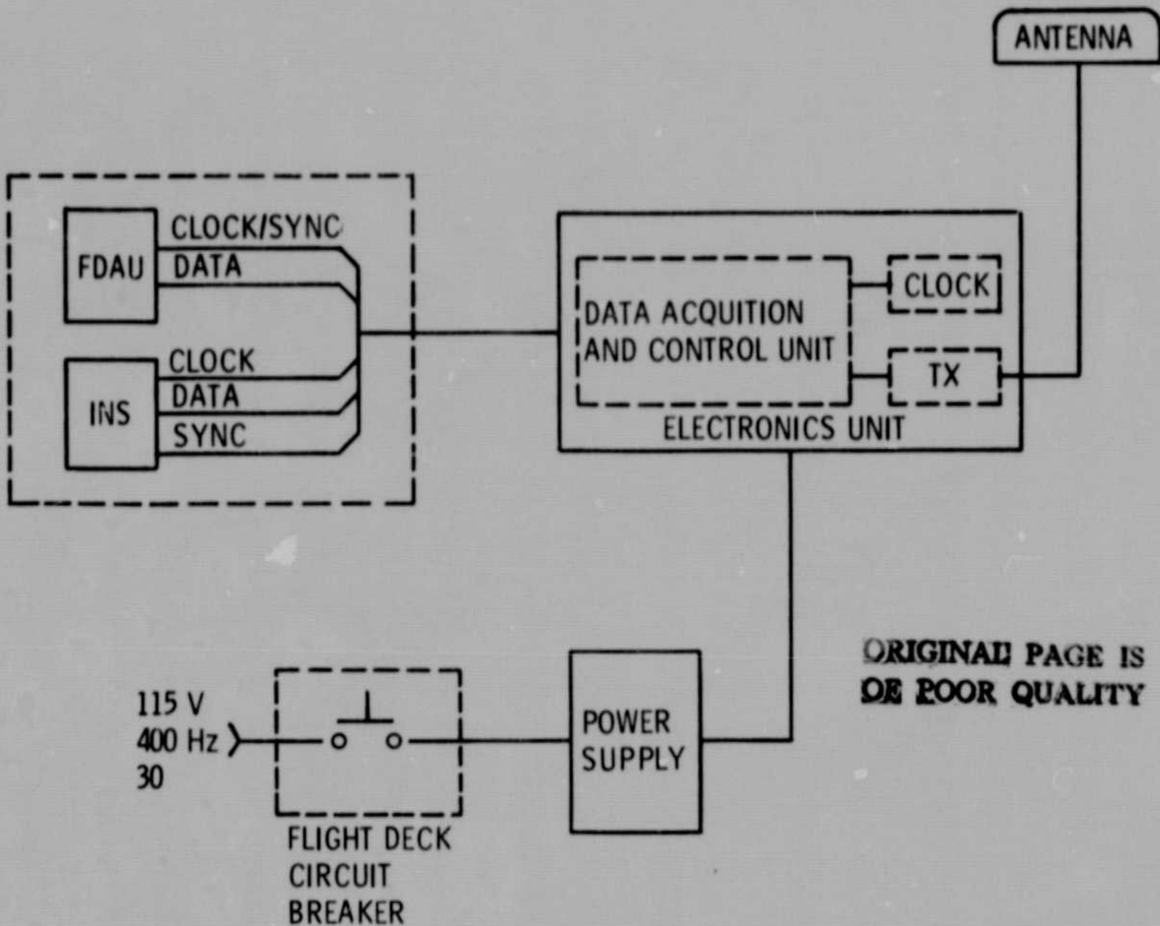


Figure 2. - Electronics unit, antenna, and power supply.



ORIGINAL PAGE IS
OF POOR QUALITY

Figure 3. - Block diagram.

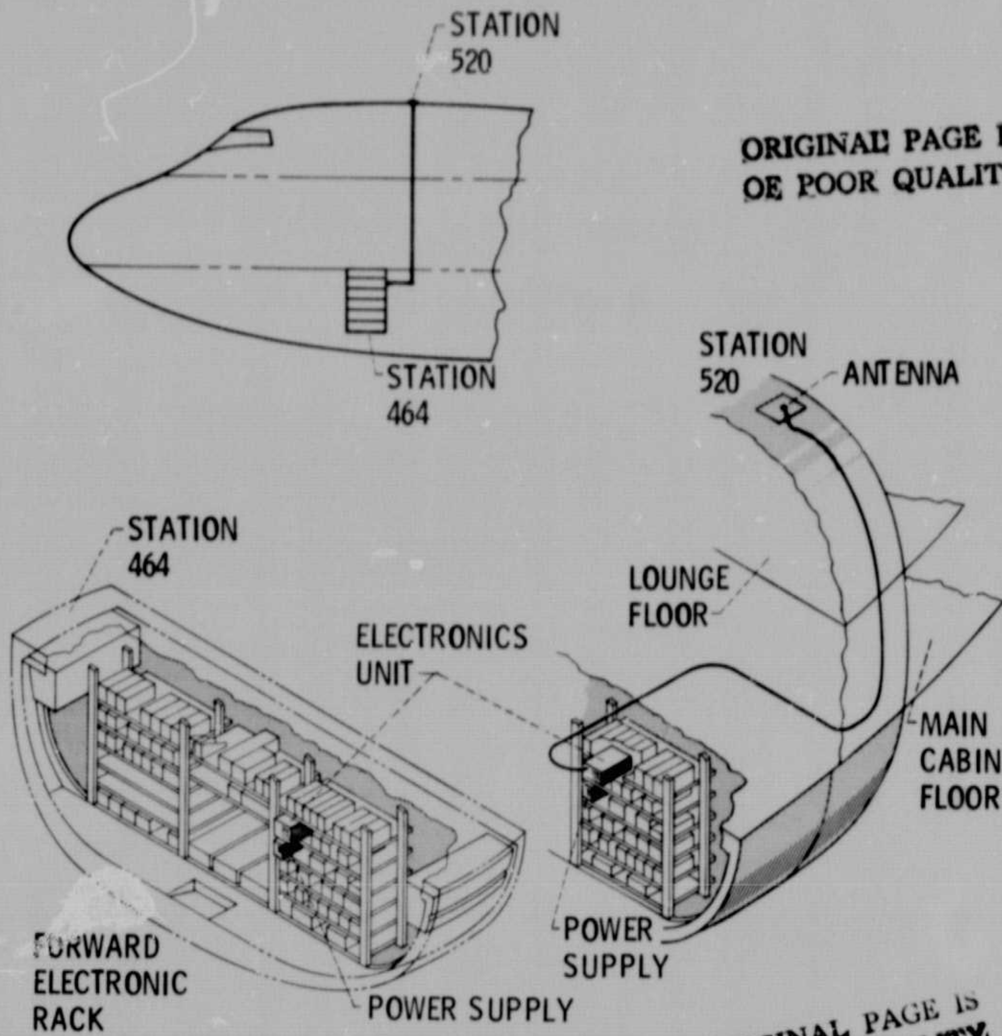


Figure 4.

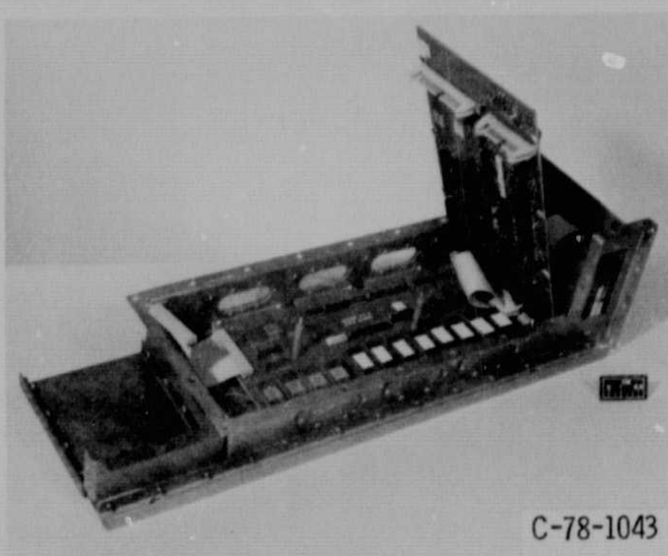
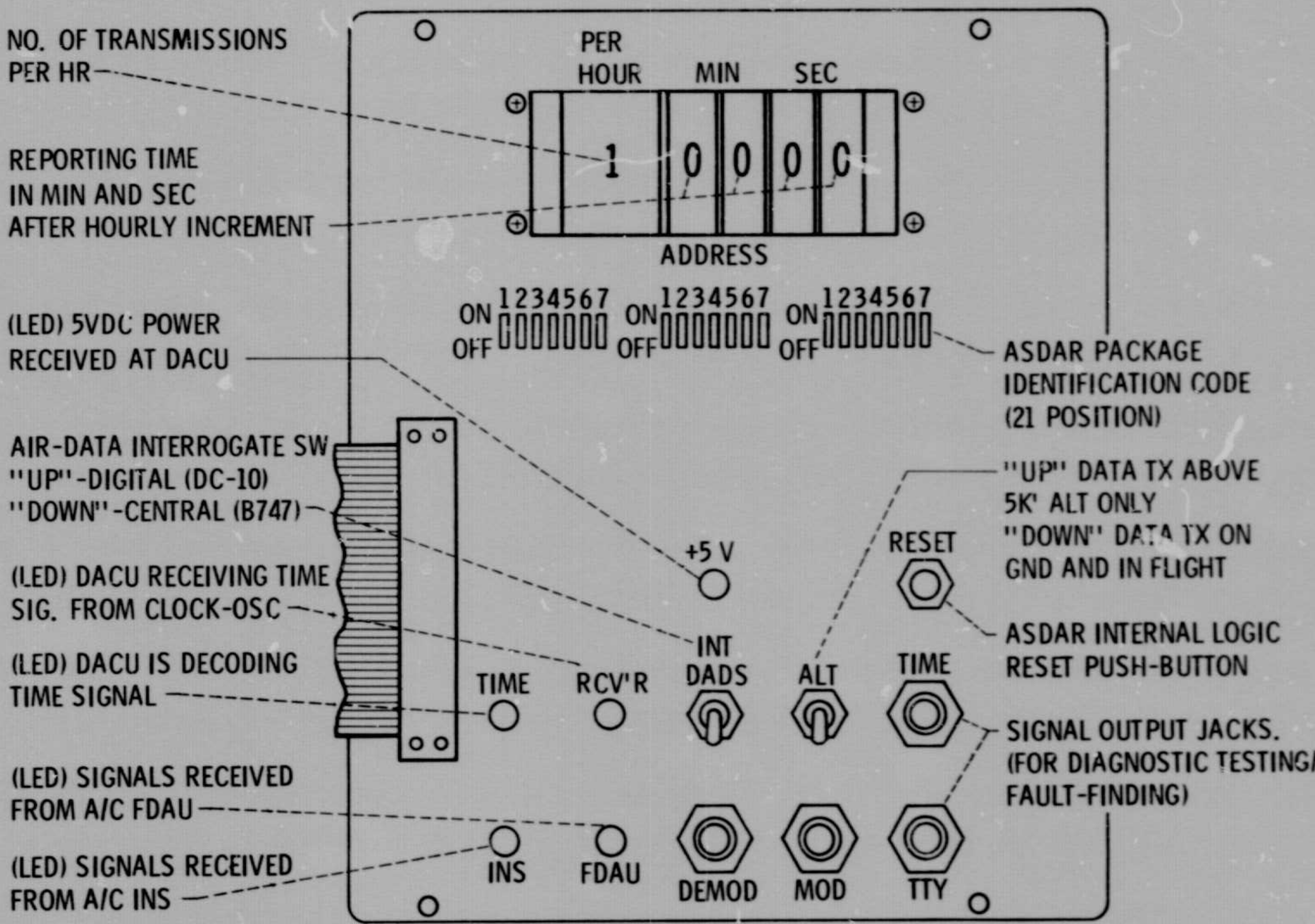
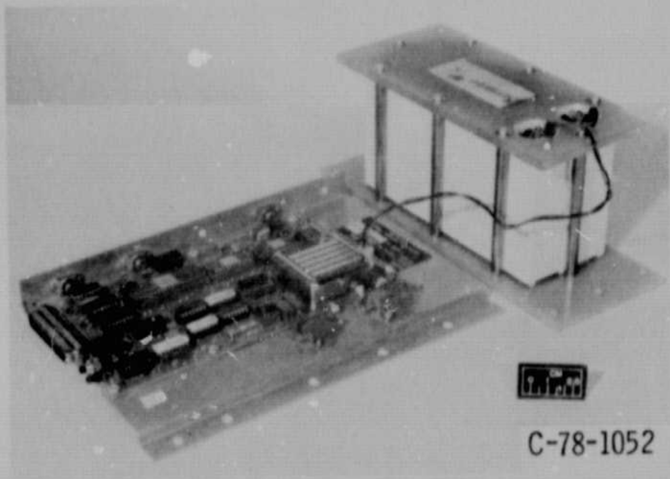


Figure 5. - Data acquisition and control unit.



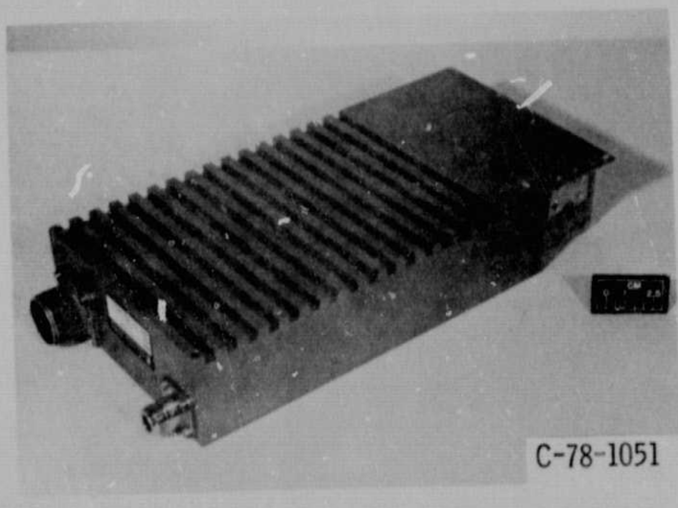
DACU FRONT PANEL CONTROLS

Figure 6. - ASDAR DTS electronics unit model 638000-2.



C-78-1052

Figure 7. - Clock and battery.



C-78-1051

Figure 8. - Transmitter.

ORIGINAL PAGE IS
OF POOR QUALITY

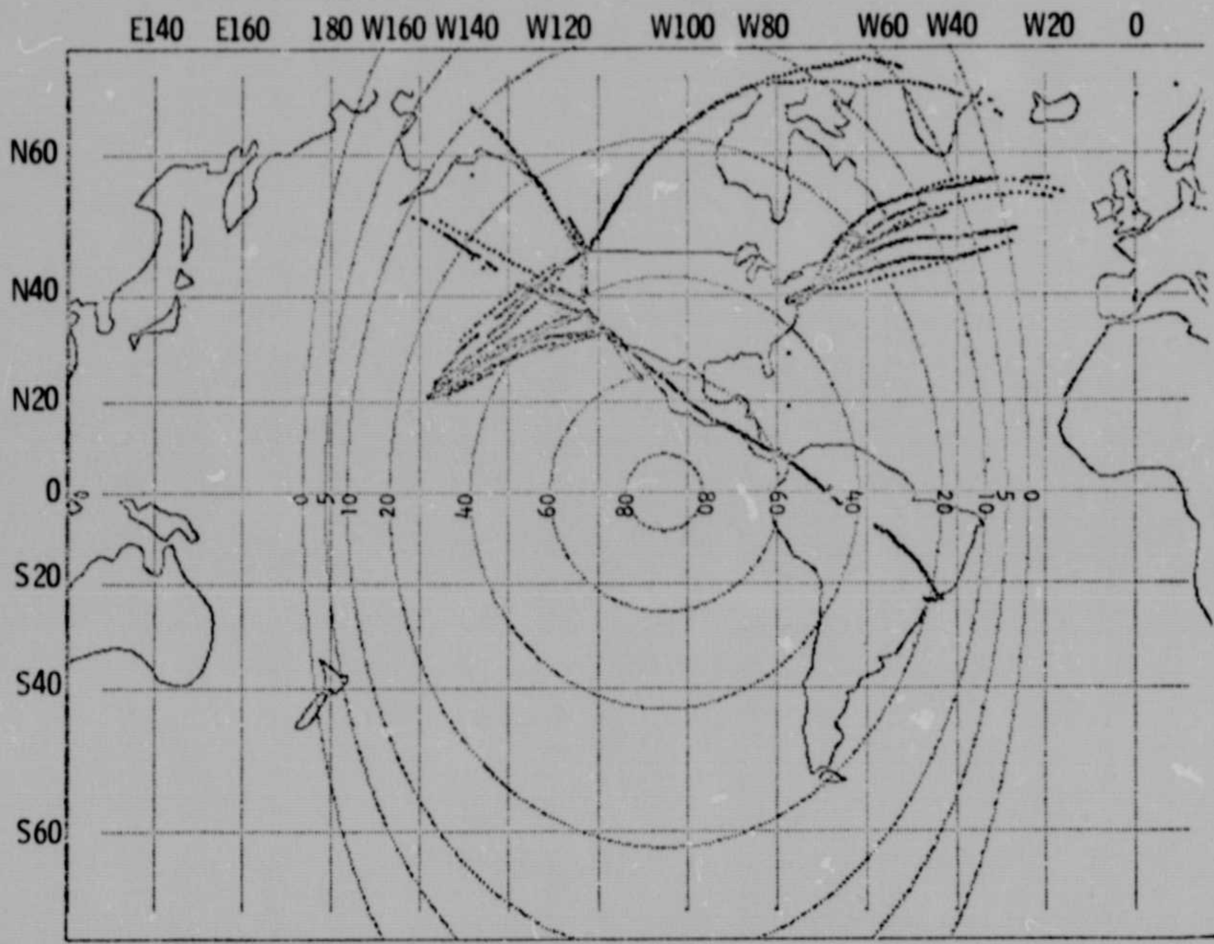


Figure 9. - ASDAR data record points with contours of constant elevation to the receive satellite.