Session X. Airborne Doppler Radar / NASA

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Description, Characteristics, & Testing of the NASA Airborne Radar

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ABSTRACT

The NASA/FAA Airborne Wind Shear Program has as its objective the development and demonstration of technology for low altitude wind shear risk reduction through airborne detection, warning, and avoidance. This paper presents the description of a coherent radar scatterometer and its associated signal processing hardware which have been specifically designed to detect microbursts and record their radar characteristics. Radar parameters, signal processing techniques and detection algorithms, all under computer control, combine to sense and process reflectivity/ clutter/microburst data. Also presented is the system's high density, high data rate recording system. This digital system is capable of recording many minutes of the in-phase and quadrature components and corresponding reciever gains of the scattered returns for selected spatial regions, as well as other aircraft and hardware related parameters of interest for post-flight analysis.

Description, Characteristics, and Testing of the NASA Airborne Radar

I. Introduction
   A. Block diagram of combined system
   B. Aircraft test configuration
   C. System Capabilities

II. Rockwell/Collins radar modifications
   A. WXR-700XN, Basic Research Radar
   B. WRT-701XN Receiver/Transmitter Characteristics
   C. WXI-711 Indicator special features

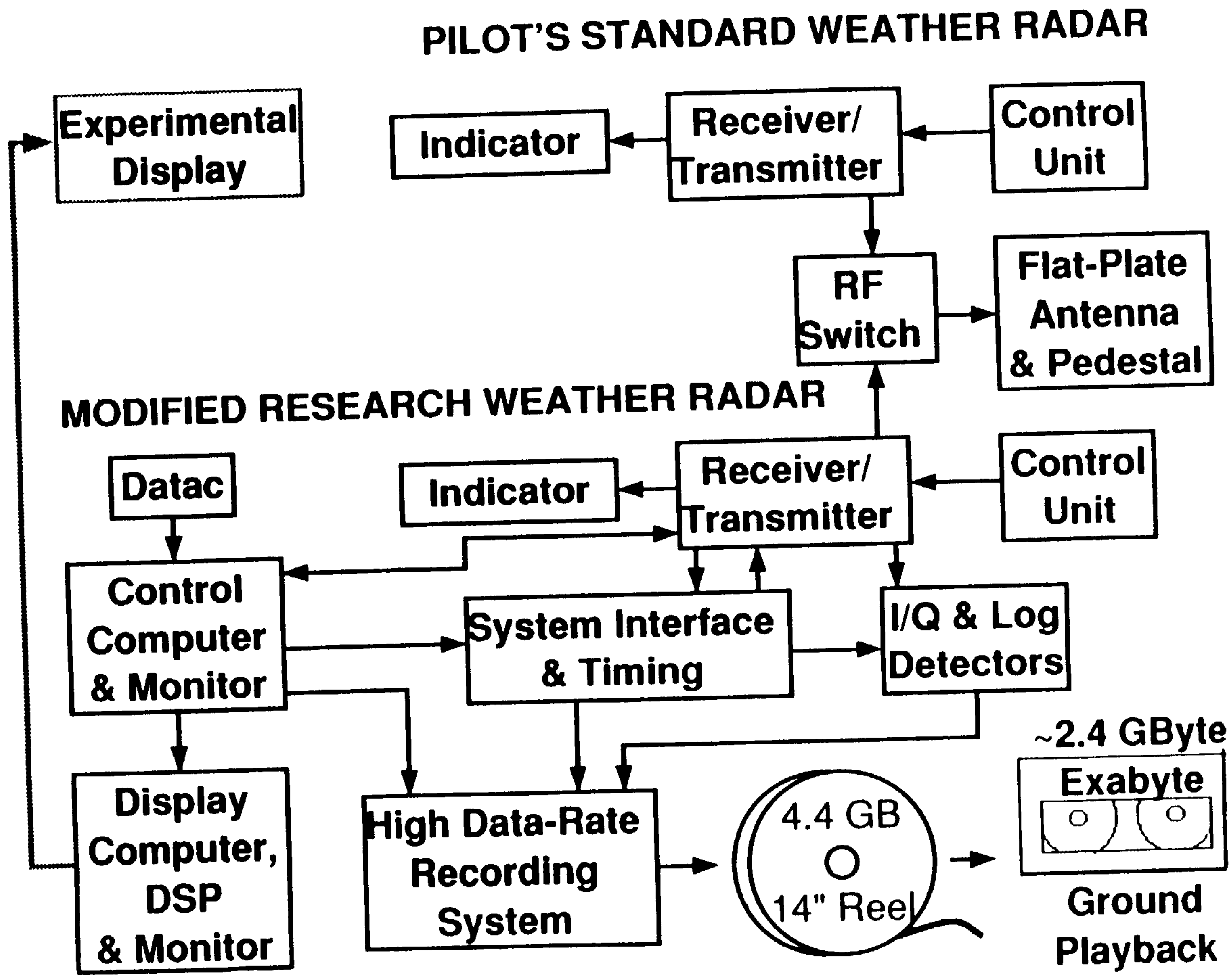
III. NASA/Langley scatterometer system
   A. Experimental system signal flow
   B. I&Q system diagram
   C. Data recording
   D. Real-Time Display Processing

IV. Status

Experimental Radar System Block Diagram

This block diagram shows the complete Wind Shear radar system. The top row of blocks shows the pilots standard system and a proposed auxiliary display of information from the experimental radar. The second row is the flat-plate antenna which is mounted in the nose of the aircraft. The lower section consists of the modified research weather radar unit from Rockwell/Collins and the NASA/Langley developed and built subsystem comprising control and display computers, system interfaces to the aircraft (DATAC), the I/Q detectors, timing circuits and data recording system.

Experimental Radar System Block Diagram



Experimental Radar System Capabilities

- Independent Data Frames 128 Pulse Repetition Periods per Frame
- Selectable Transmitter Parameters
  - PRF (Will use 9581, 4791, 3755, 2395, 1198 Hz)
  - Pulse Width (Will use ~ 1, 2, 4, or 8 μs)
  - Dual X-Band Transmit Frequencies
- Selectable Antenna Parameters
  - Scan Pattern (az, el, az/el)
  - Scan Rate (3 Frames/1.5°)
- Independent AGC for each Range Bin (>60 dB)
- Fast I.F. Gain Control (<0.5 μs)

Experimental Radar System Capabilities Continued

- Selectable Range Bin Sampling of up to 124 bins to be recorded and processed out of 81 to 843 (depending on PRF & pulse width) available from R/T unit

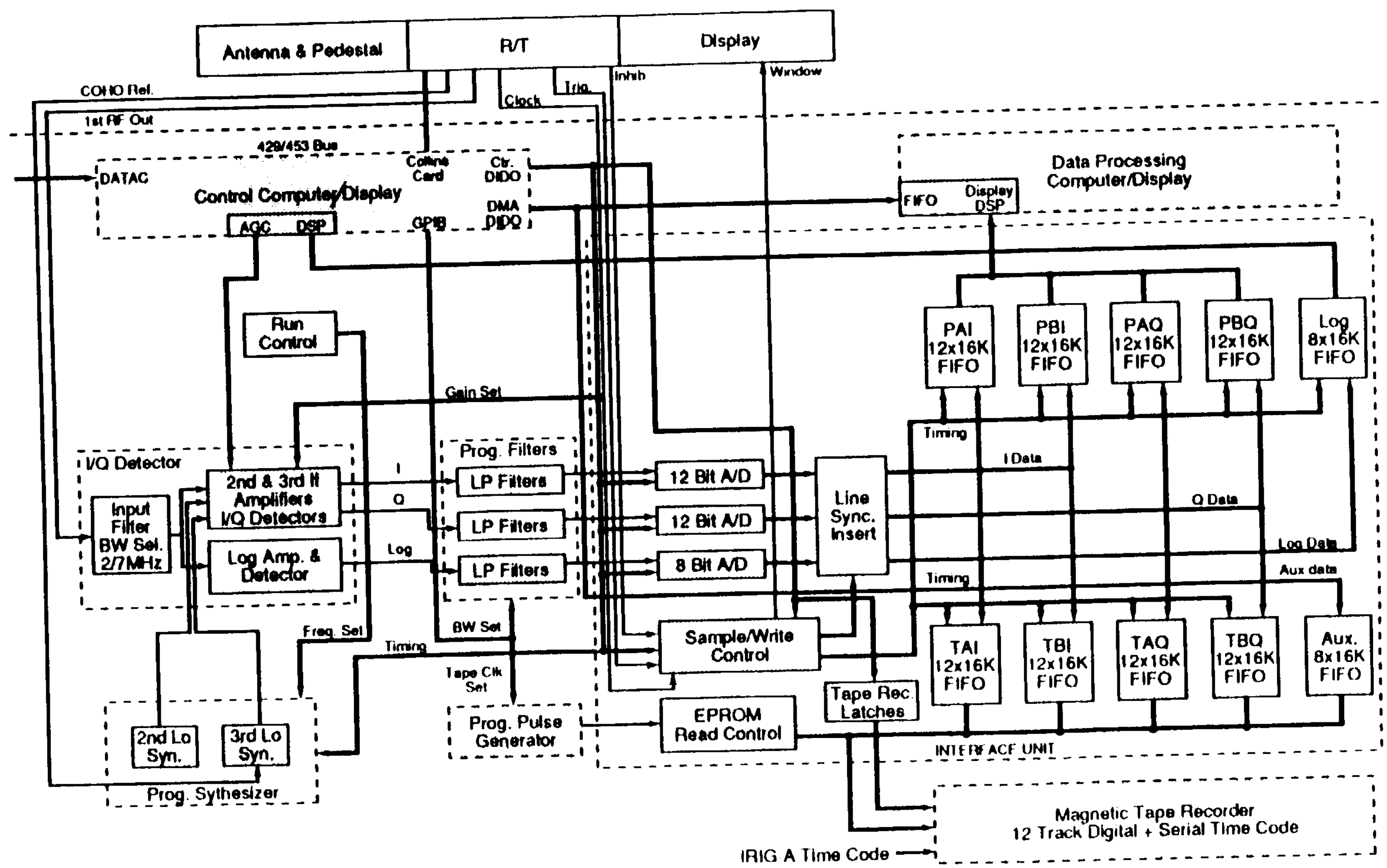
- Capability of skipping 0, 1, 2, or 3 Range Bins for each one selected

- "Second Range Mode" in which every other transmit pulse is inhibited in order to study effects of range aliasing

Wind Shear Experimental Radar - Functional Block Diagram

This block diagram shows the major functional components of the NASA/Langley Experimental Radar in some detail. The Rockwell/Collins modified R/T unit has analog and digital interfaces to the remainder of the system. The analog outputs from the R/T unit consist of the Coherent Reference (COHO ref.), used to lock the phase of the 3rd local oscillator (3rd LO) for the 3rd IF in the NASA I/Q Detector, and the 1st IF (mislabeled 1st RF Out on the diagram) which provides the "video" signal to the I/Q Detectors. Digital output lines from the R/T carry the clock signal (used to synchronize an 8 phase clock in the NASA portion of the system), the Frame Trigger (Trig.) which denotes the start of a new 128 pulse frame of data, and the Inhibit (Inhib.) signal which indicates when alternate transmit pulses are being inhibited in the Range Alias mode. Communications between the R/T unit and the NASA control computer are carried out over ARINC 429 (control) and ARINC 453 (data) serial busses. The control computer also houses a number of other interface cards. A DATAC interface card used to acquire data from the aircraft data systems. A GPIB/IEEE-488 interface card provides for control of the Programmable Low Pass (anti-aliasing) Filters and the Programmable Pulse Generator used for tape recorder timing. A DSP card and an associated interface card implement digital bin-to-bin Automatic Gain Control (AGC) using averages (for each bin) of the log detector output over a portion of each frame to calculate attenuator settings for the next frame. The Sample/Write control circuit generates timing signals to clock data into FIFO buffers and to insert "line sync" word patterns in the I&Q digital data stream at the beginning of each line of data corresponding to the set of returns from a single transmit pulse. The Tape and Processing I&Q buffers are organized in a ping-pong arrangement where the A buffers are filled first, followed by the B buffers. Digitized data flows to the Tape and Processing FIFOs in parallel. While the B buffers are being clocked out to tape (based on signals from the Read Control circuit) or read by the Display Processing Computer, the A buffers are being filled with digitized data from the A/D converters. The auxiliary Data FIFO and a similar FIFO hosted in the Display Processing Computer are simultaneously filled with data by the Control Computer. This auxiliary data includes aircraft data from the DATAC system, hardware status and control words, Collins R/T information from ARINC 429 (Control) and ARINC 453 (Data) bus interfaces, and bin-to-bin AGC log channel averages. This data is clocked out to tape at the beginning of each frame of 128 pulses.

WINDSHEAR EXPERIMENTAL RADAR-FUNCTIONAL BLOCK DIAGRAM



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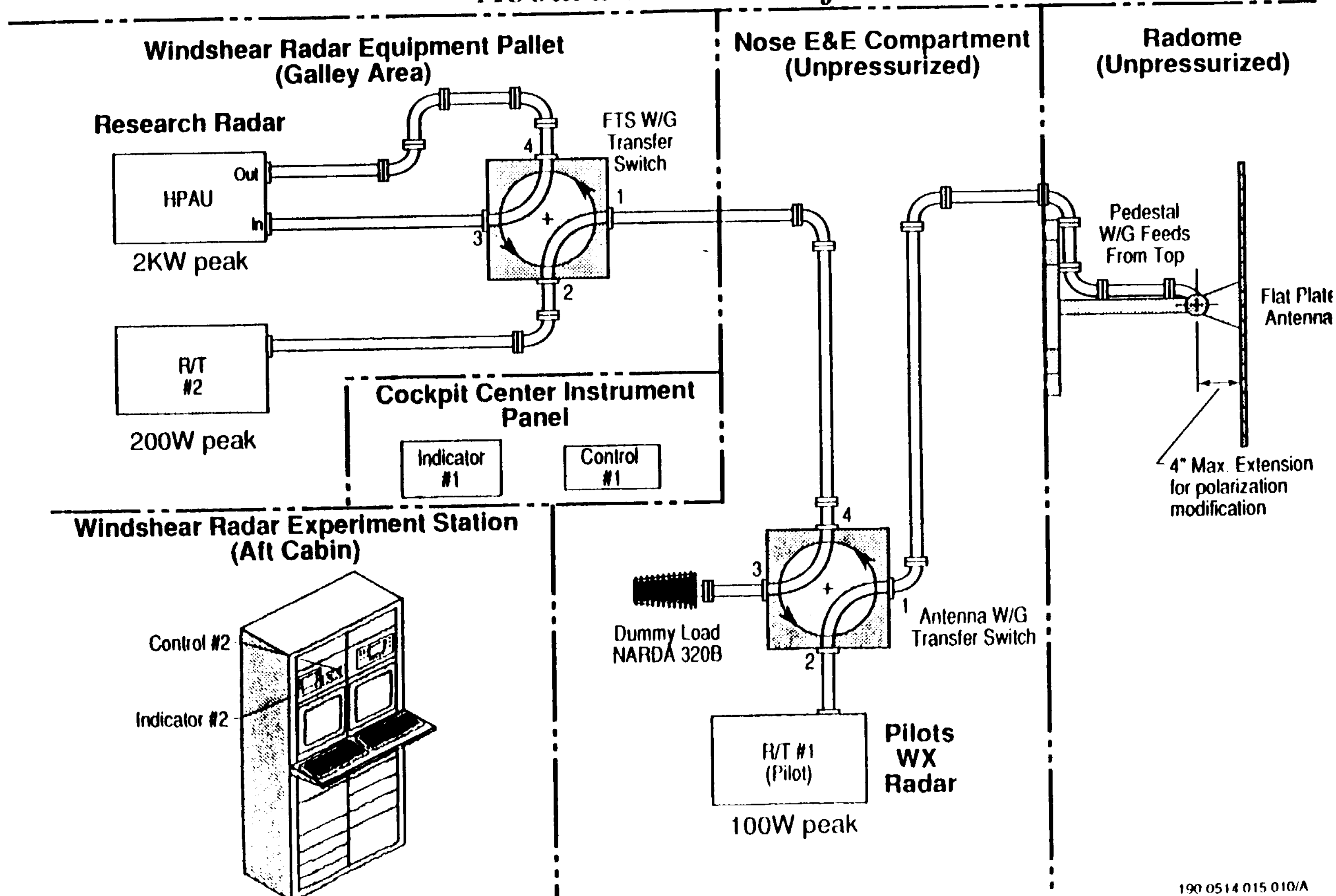
W/S Radar Waveguide & Component Location Aboard Test Aircraft

The Experimental Windshear Radar System components are distributed in several locations in the NASA/Langley 737 aircraft. The Antenna and Pedestal are mounted behind a radome in the nose of the aircraft. This assembly is fed by waveguide routed through a waveguide switch located near the pilot's Standard Weather Radar unit in the nose E&E compartment. This waveguide switch is controlled by the pilot and allows switching between the Standard and Experimental R/T units. The unused system's output is fed to a Dummy Load to prevent unwanted radiation into the interior of the aircraft. The pilot's Indicator (Display) and Control units are interfaced to the Standard R/T via ARINC 429 and 453 buses. The experimental R/T unit and 2 KW High Power Amplifier Unit are located aft of the cockpit in the galley area. Another waveguide switch, controlled by the Experimental R/T unit, switches the HPAU in and out of the system as requested by the experimenters at the dual bay Wind Shear Radar Experiment Station located near the tail in the aft cabin. Connections from the Experiment Station to the Experimental R/T unit include ARINC 429 and 453 buses, and coaxial cables carrying 1st IF, Coherent Reference, and monitor signals.

W/S RADAR WAVEGUIDE & COMPONENT LOCATION
Aboard Test Aircraft

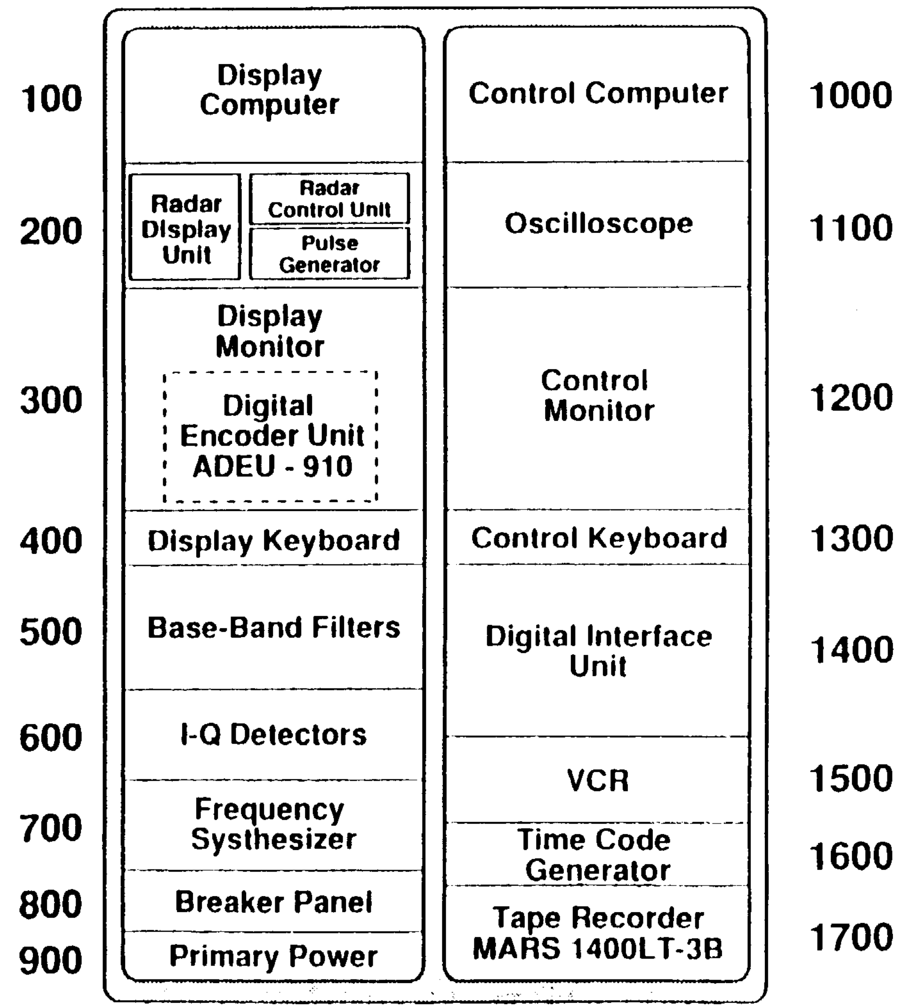


Console Equipment Arrangement

This figure shows the location of various components of the Experiment Station portion of the system in the dual bay rack.

WINDSHEAR RADAR FLIGHT EXPERIMENT

Console Equipment Arrangement



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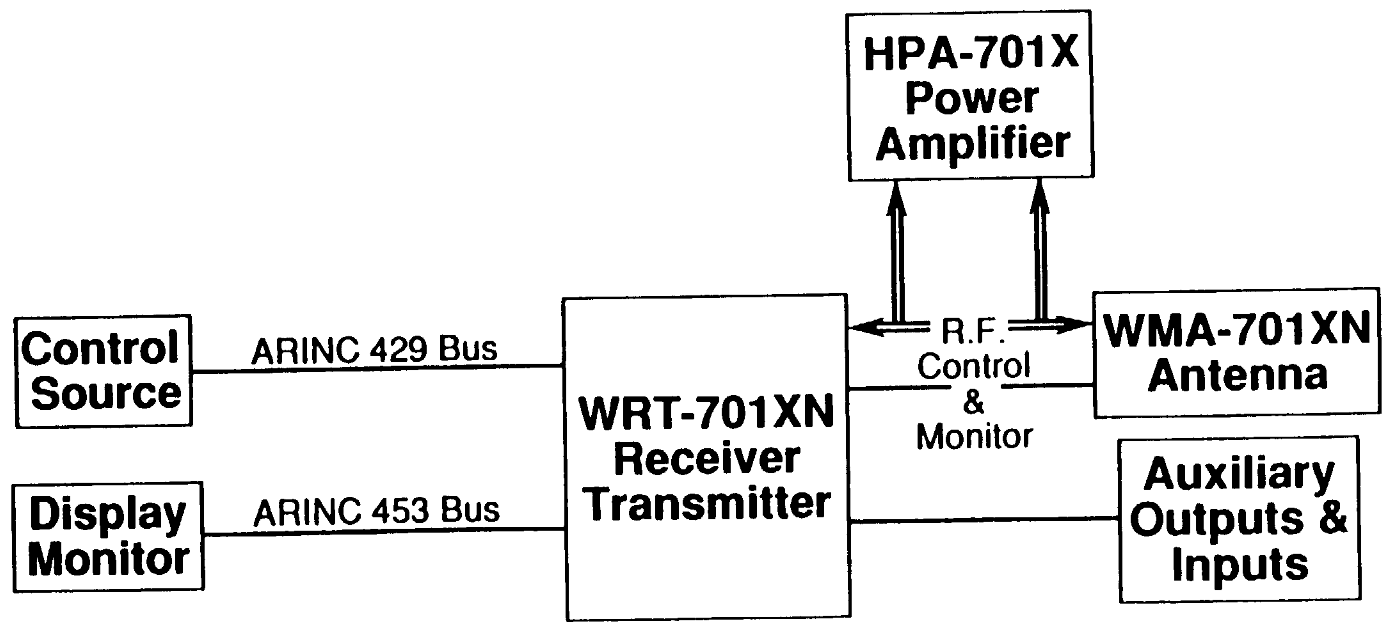
WXR 700 XN Research Radar System

This block diagram shows the Rockwell Collins supplied modified Weather Radar system components. This system can operate as a stand-alone radar but will generally be operated as an integral part of the NASA/Langley Experimental Wind Shear Radar system.

BLOCK DIAGRAM, WXR700XN RESEARCH RADAR SYSTEM

ROCKWELL INTERNATIONAL, COLLINS



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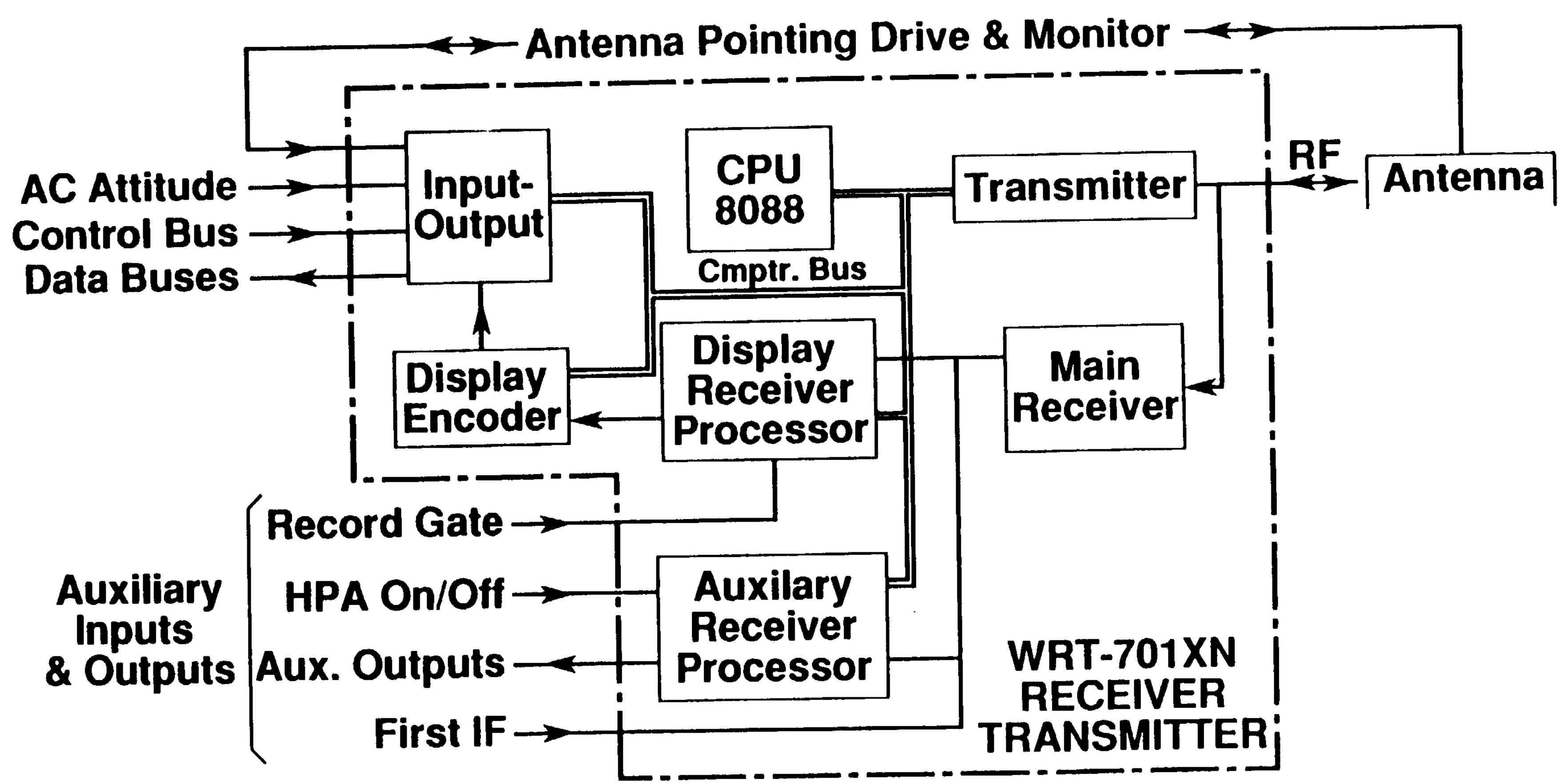
WRT 701 XN Receiver/Transmitter

This simplified block diagram illustrates the internals of the Collins R/T unit and the interfaces which allow it to be integrated as a component of the NASA/Langley system. The AC Attitude control is an ARINC 429 bus, separate from the ARINC 429 Control bus driven by the Control Computer, which supplies roll and pitch information used to be used by the R/T unit in compensating for effects of aircraft motion on antenna pointing. The First Intermediate Frequency output (erroneously shown as an input) provides to signal input to the NASA/Langley developed portion of the system. A coherent reference is also provided as an output in order to allow coherent detection to be employed to generate In-phase and Quadrature components of the radar return.

SIMPLIFIED BLOCK DIAGRAM, WRT 701XN RECEIVER TRANSMITTER



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HPA 701 XN Power Amplifier

The HPAU traveling wave tube amplifier provides a 10 dB or greater increase in transmitted power to provide greater signal strength.

HPA-701XN POWER AMPLIFIER

- Traveling wave tube amplifier.
- Amplifies WRT transmit output.
- 2650 Watts peak.
- Provides receive signal path, antenna to WRT.

WMT 701 XN Antenna

The antenna is the same flat plate unit supplied with Collins' Standard Weather Radar but a n additional rotational joint has been added to the positioner to allow a 90 degree rotation of the antenna to provide either horizontal or vertical polarization in order to allow investigation of any polarization effects which might aid in separating signals resulting from weather from those produced by ground clutter.

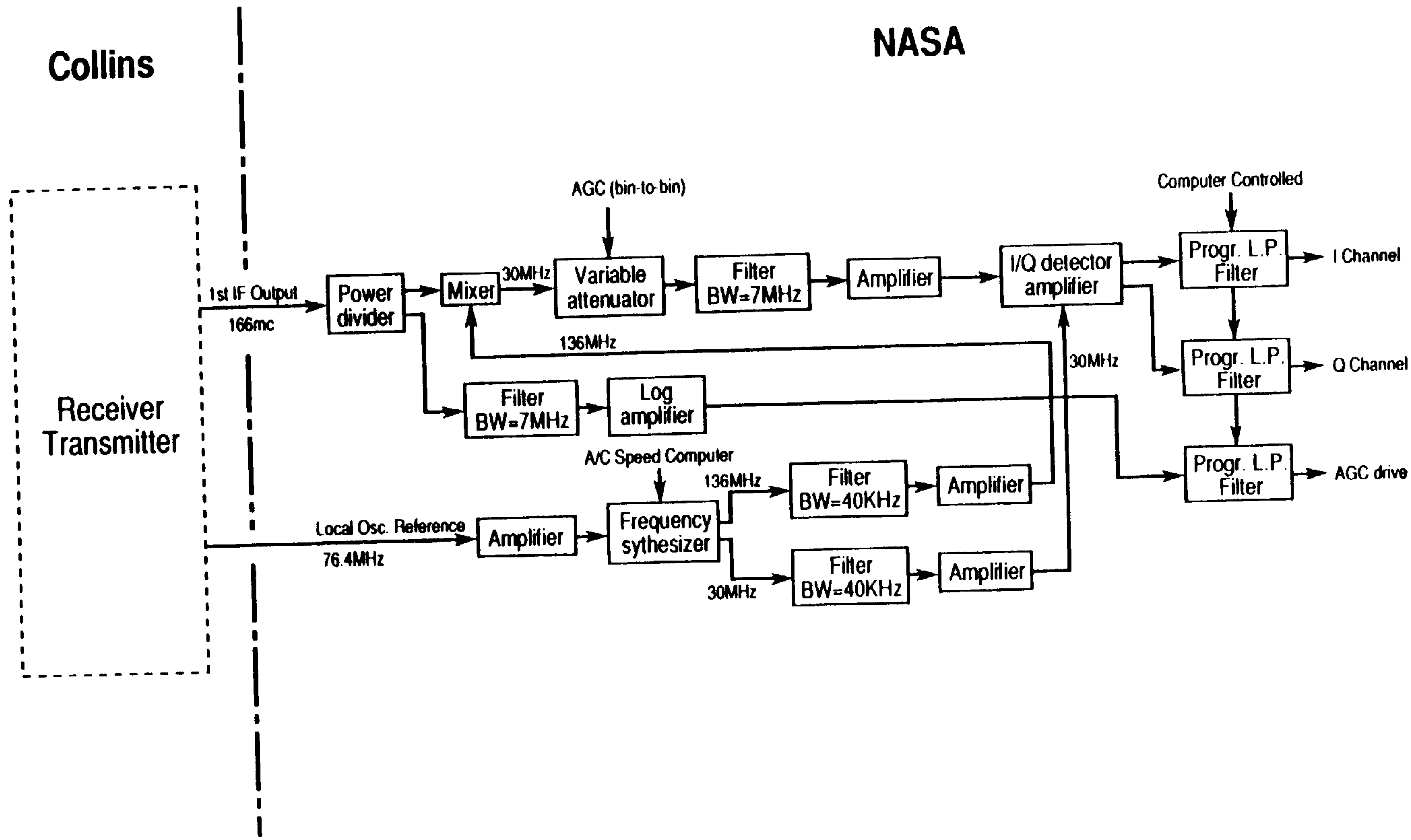
WMT-701XN ANTENNA

- Flatplate radiator with supporting pedestal.
- Pointing is controlled by the computer in the WRT-701XN receiver transmitter.
- Stabilized with aircraft attitude inputs.
- Selectable horizontal or vertical polarization.

Research System Detector (simplified) Block Diagram

The NASA system incorporates synchronous detection to provide In-phase and Quadrature components of the radar signal. A log detector is used to drive a Digital Signal Processing card, implementing a feed forward bin-to-bin digital Automatic Gain Control system which sets three programmable attenuators in the I&Q signal path in order to minimize system noise and keep the signal within the dynamic range of the 12 bit A/D converters.

RESEARCH SYSTEM DETECTOR BLOCK DIAGRAM



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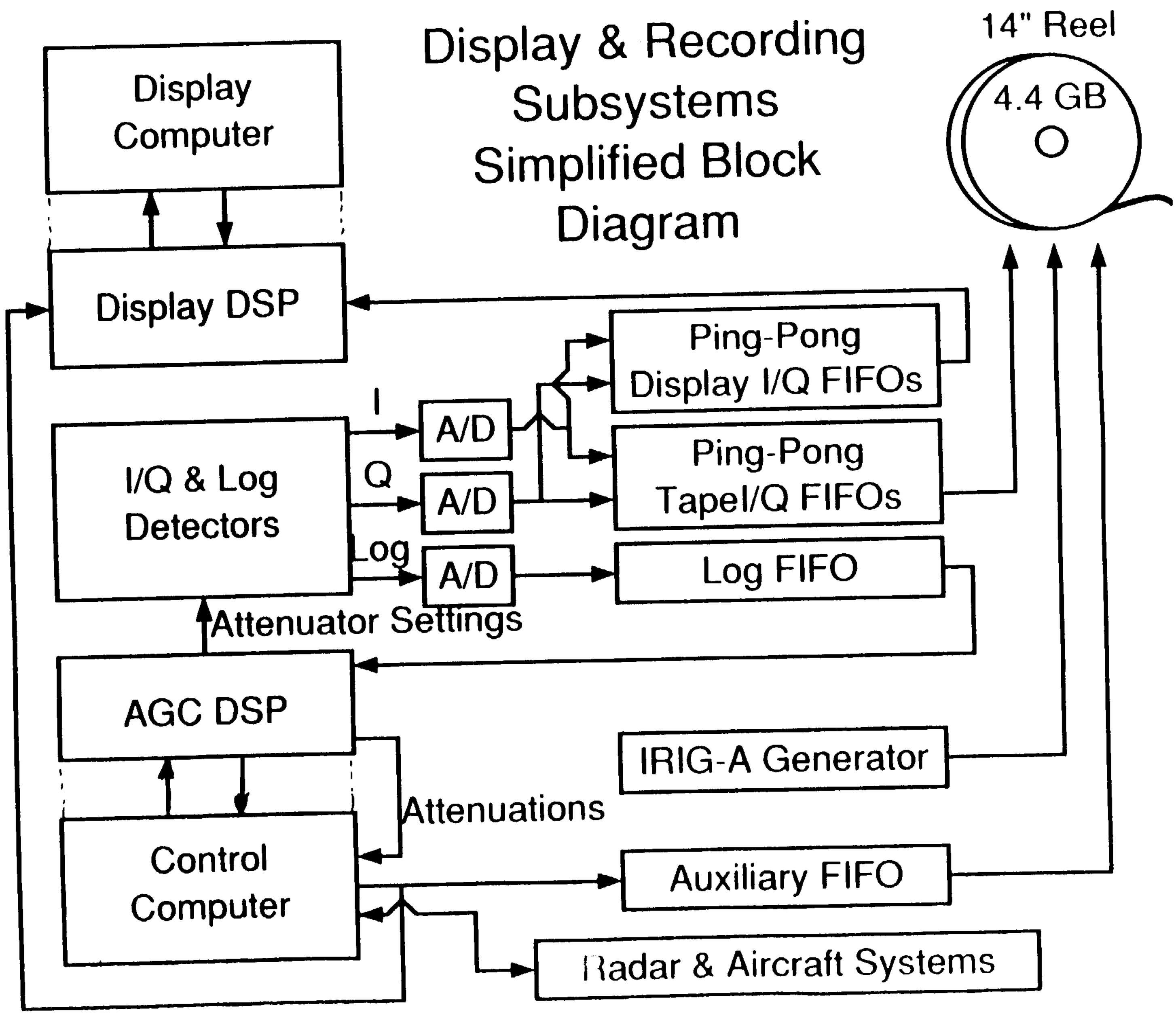
Display and Recording Subsystems Simplified Block Diagram

The primary goal of the current stage of the Wind Shear Radar Experiment is to collect data on tape for post-flight analysis. The I&Q and AUX data streams are recorded on a Kodak Datatape 1" 14 track tape unit providing up to 4.4 GBytes of storage at data rates up to 1.6 million 12 bit digital words per second. One channel is used in direct or analog mode to record an IRIG-A (10 KHz carrier) time code signal used to locate desired segments of data on playback. The last channel is used by the tape recorder's error detection and correction circuitry.

Display & Recording Subsystems Simplified Block Diagram



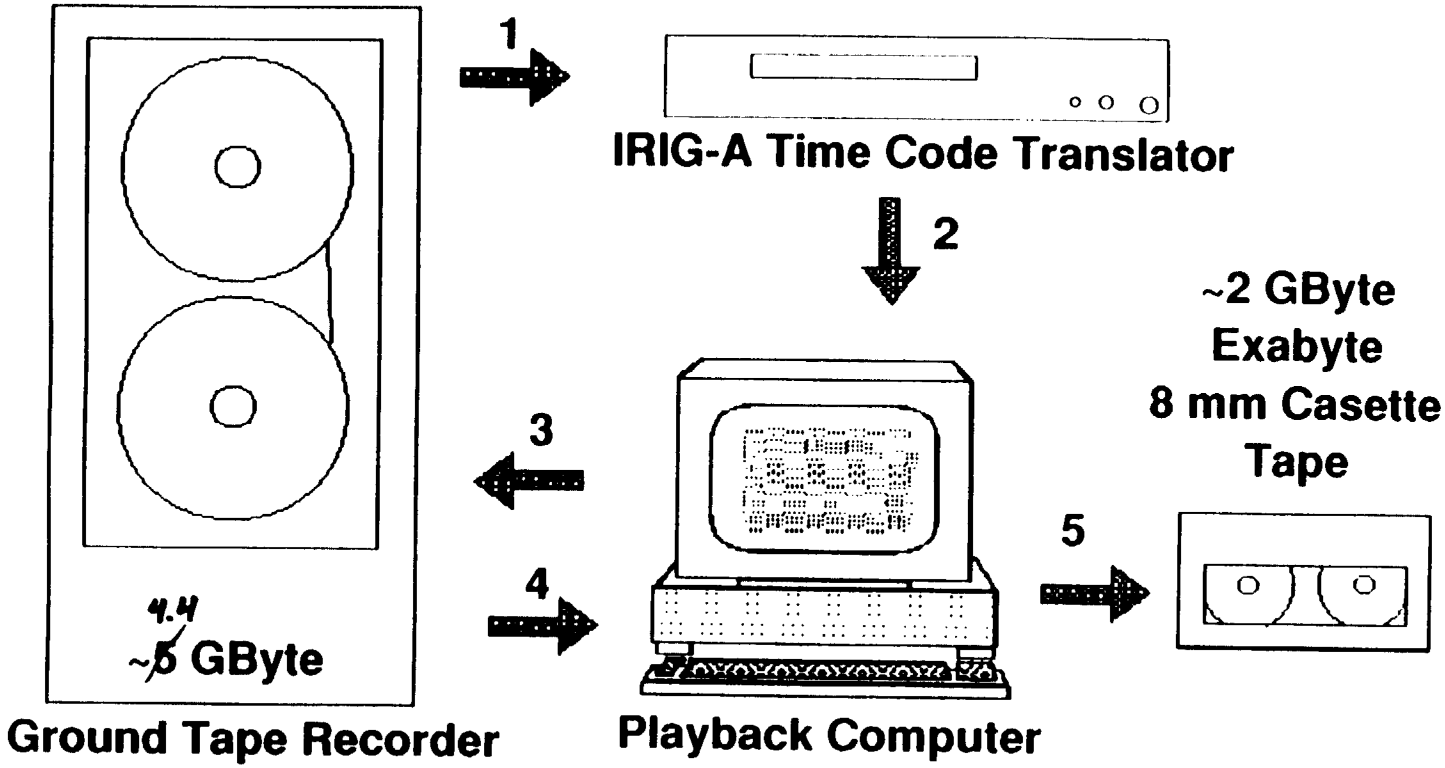
Experimental Radar Data Recording and Display System Capabilities

- Raw Data Recorded for each Selected Range Bin for every Transmitted Pulse (12 Bits each for I&Q)
- Complete Auxiliary Data (AGC values; Aircraft, Radar & Hardware Parameters; Run Header Information) Recorded for every 128 pulse Frame
- $>10^9$ Data Samples/14" Reel of Magnetic Tape
- Data Rates up to 2.4 MBytes/sec or 800,000 I/Q samples/sec
- 16K Data Samples Held in FIFO Temporary Storage for Display Processing
- Display Computer Controls Data Access Rate

Wind Shear Data Playback Process

A Compaq 386/20 AT compatible computer is used to play back data from the 14 track flight tapes at a ground based playback station. The data is dumped to a 500 MByte hard disk at a continuous 50,000 word/second rate. Each disk full of data is transferred to an 8mm Exabyte Cassette Tape in a format which can be read by the Interactive Systems Corporation UNIX based analysis software. On the UNIX system the data is then loaded into an Informix database system where it can be accessed by analysts.

Windshear Data Playback Process

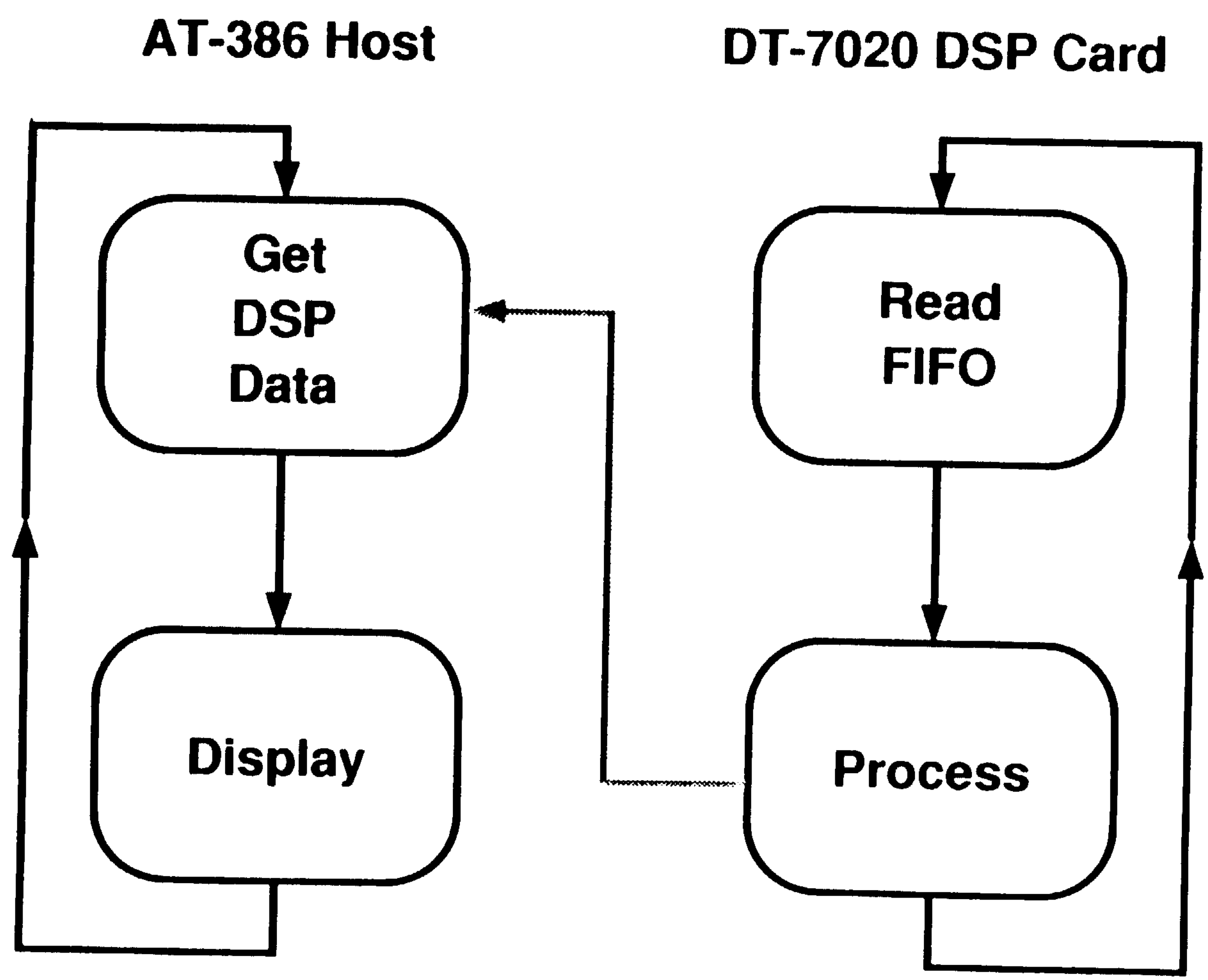


1 Serial Time Code (IRIG-A, 10 KHz Carrier - direct channel)
2 Time Code Translator produces digital output to computer
3 At time determined by flight log, computer initiates dump
4 12 bit flight data (I&Q and Auxiliary) to 16 bit words on disk
5 Disk file to 8mm Exabyte Tape for analysis system use

Real-Time Display Processing

A quick-look real-time display has been implemented as part of the Experiment Station on the aircraft. This system consists of a Data Translations DT7020 DSP board hosted in a Texas Microsystems B386 20 MHz rack mounted PC/AT compatible system. The DT7020 card is loaded with data acquisition and processing routines by the 80386 host processor. The DSP board acquires data from the I&Q Processing FIFOs, via a DT-Connect parallel interface, and from the Auxiliary data stream provided by the Control Computer. This data is processed in a continuous loop and the processed data is available to a program running on the host which can then provide a variety of display formats. This system is a valuable diagnostic tool and will aid in effectively using the system to collect data for later analysis. In a later stage of the program a more powerful real-time computer system is planned in order to demonstrate wind shear hazard detection in real time using more sophisticated algorithms than are possible on the DSP board.

Real-Time Display Processing



Experimental Radar Real-Time Display Operational Modes

- Derived Velocity vs Range along range line, with or without doppler filter
- Received Power vs Range along range line, in dBm or dBz
- FFT of 6 selected Range Bins across 1 frame of 128 pulses
- Color map of velocity/range over full azimuth scan, with or without doppler filter
- Color map of hazard/range over full azimuth scan
- Color map of hazard/range over full azimuth scan with wind shear tracking and alarm algorithms included (demonstration mode)

NASA Experimental Radar Status

- Radar system is currently undergoing the final stages of component testing and integration in the laboratory at NASA Langley.

- After the completion of system integration, operational testing will performed with the antenna system installed on the roof of Building 1299 at Langley. Weather and ground targets will be used as available. During this period, development of real-time and analysis software will continue.

- It is planned to install the system on the Langley 737 aircraft in early January 1991 and begin flight testing, calibration, and clutter and weather data collection.

OA

OVERVIEW

OF THE

WXR-700XN RESEARCH RADAR SYSTEM

PART OF THE

NASA AIRBORNE RESEARCH RADAR SYSTEM

PRESENTED BY

ROCKWELL INTERNATIONAL - COLLINS

OCTOBER 16-18, 1990

CONTENTS

WXR-700XN RESEARCH RADAR SYSTEM

CONTROL SOURCES

DISPLAY MONITOR

HPA-701XN POWER AMPLIFIER

WMT-701XN ANTENNA

WRT-701XN RECEIVER TRANSMITTER

FIGURES

FIGURE 1 BLOCK DIAGRAM, WXR-700XN RESEARCH RADAR SYSTEM

FIGURE 2 AIRCRAFT CONTROL AND DISPLAY SUBSYSTEM

FIGURE 3 GROUND CONTROL AND DISPLAY SUBSYSTEM

FIGURE 4 SIMPLIFIED BLOCK DIAGRAM: WRT-701XN RECEIVER TRANSMITTER

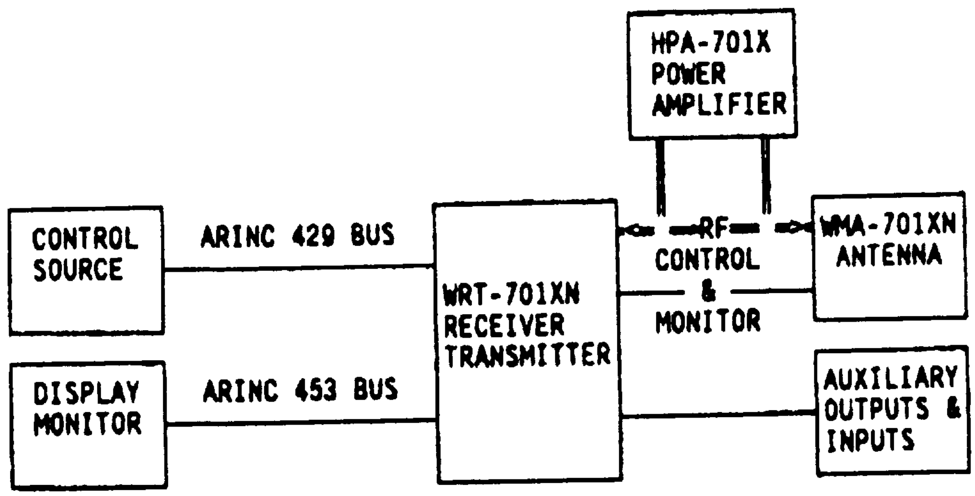


FIGURE 1 BLOCK DIAGRAM, WXR-700XN RESEARCH RADAR SYSTEM

WXR-700XN RESEARCH RADAR SYSTEM (FIGURE 1)

CONTROL SOURCES

TEST COMPUTER (IBM COMPATIBLE) AND CDIO-701XN COMPUTER INTERFACE CARD WITH NASA OR COLLINS SOFTWARE IN COMPUTER (FIGURE 2).

COLLINS WDP-701 WEATHER DISPLAY PROCESSOR USED IN CONJUNCTION WITH A PERSONAL COMPUTER SYSTEM AND COLLINS SOFTWARE. (FIGURE 3)

DISPLAY MONITOR

WXI-711 INDICATOR (FIGURE 2)

COLOR RGB TV MONITOR USED WITH WDP-701 (FIGURE 3)

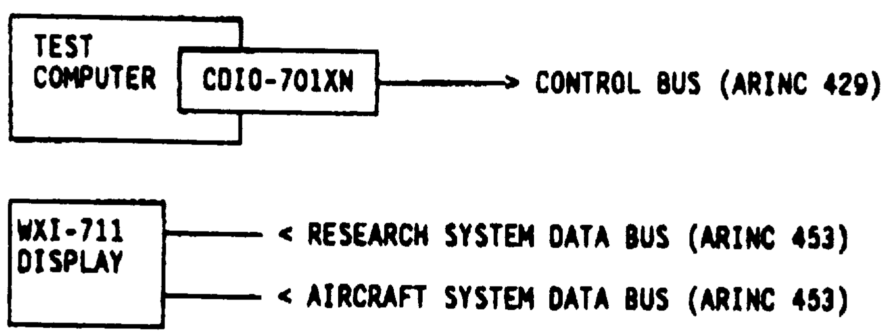


FIGURE 2 AIRCRAFT CONTROL AND DISPLAY SUBSYSTEM

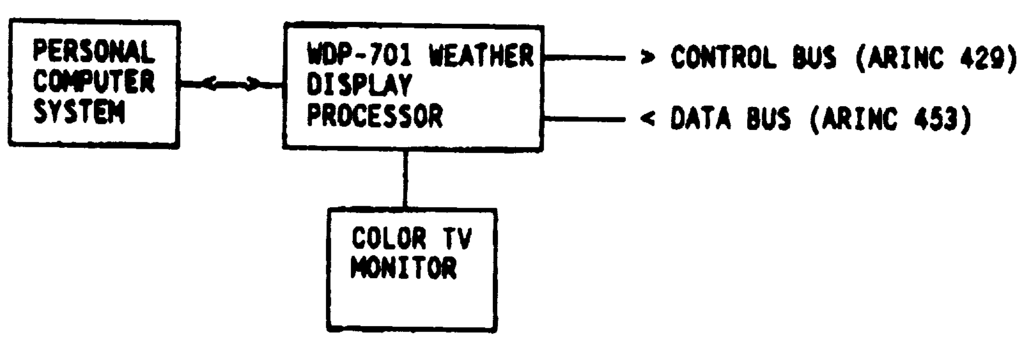


FIGURE 3 GROUND CONTROL AND DISPLAY SUBSYSTEM

HPA-701XN POWER AMPLIFIER

TRAVELING WAVE TUBE AMPLIFIER

AMPLIFIES WRT TRANSMIT OUTPUT

2650 WATTS PEAK

PROVIDES RECEIVE SIGNAL PATH, ANTENNA TO WRT

WMT-701XN ANTENNA

FLATPLATE RADIATOR WITH SUPPORTING PEDESTAL

POINTING IS CONTROLLED BY THE COMPUTER IN THE WRT-701XN RECEIVER TRANSMITTER

STABILIZED WITH AIRCRAFT ATTITUDE INPUTS

SELECTABLE HORIZONTAL OR VERTICAL POLARIZATION

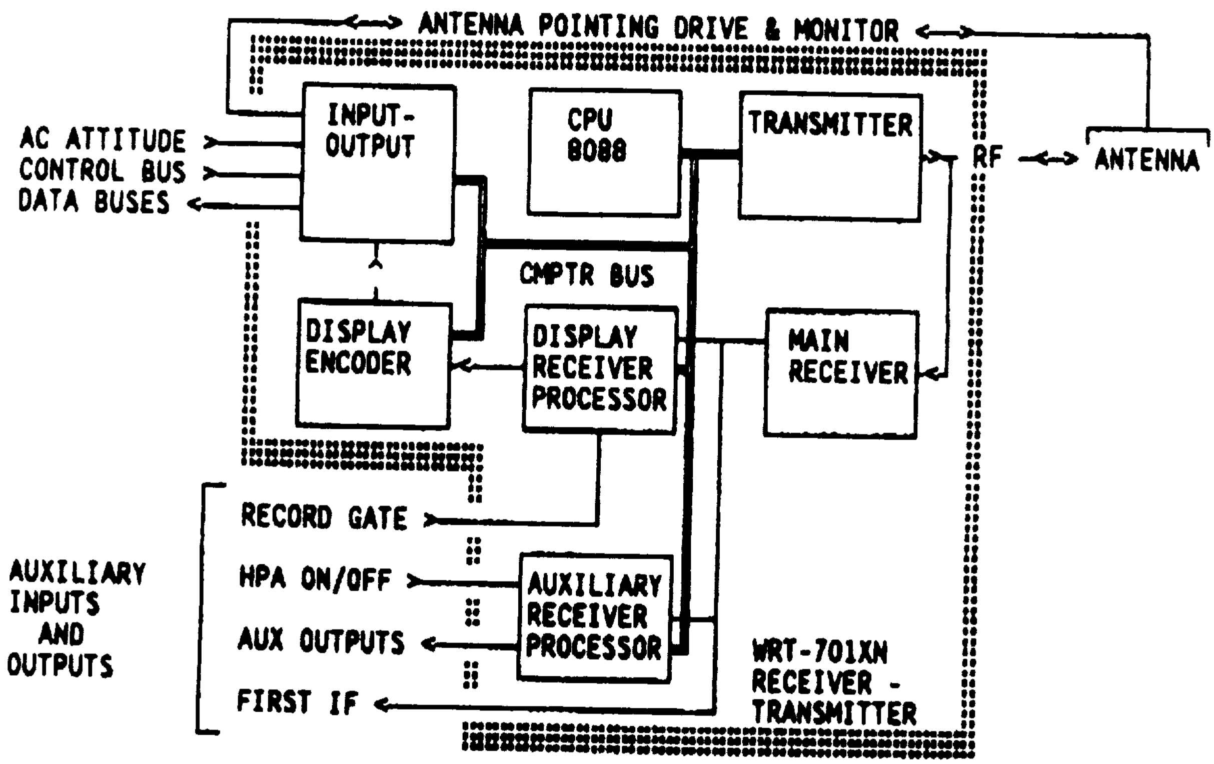


FIGURE 4 SIMPLIFIED BLOCK DIAGRAM, WRT-701XN RECEIVER TRANSMITTER

WRT-701XN RECEIVER TRANSMITTER (FIGURE 4)

CONTROL BUS INPUT (ARINC 429 BUS) ESTABLISHES THE OPERATING CONFIGURATION.

INTERNAL COMPUTER (8088 CPU) CONFIGURES THE SYSTEM VIA THE COMPUTER BUS.

TRANSMITTER - SELECT FREQUENCY, PULSE WIDTH PRF, LOW OR HIGH PEAK POWER

DISPLAY RECEIVER PROCESSOR - BANDWIDTH, RANGE, GAIN, STC, AND MODE (WEATHER, MAP, VELOCITY, ...)

DISPLAY ENCODER - SELECT ENCODING BASED UPON OPERATING MODE

AUXILIARY RECEIVER PROCESSOR - SELECT GAIN, INITIAL STC FOR MATCHED BANDWIDTH, STC SLOPE 0, 6 OR 9 dB/OCTAVE

ANTENNA - SETS UP AND EXECUTES REQUESTED POINTING ROUTINES, USES AIRCRAFT PITCH & ROLL TO COMPUTE POINTING POSITION, ISSUES DRIVE COMMANDS AND MONITORS ANTENNA POSITION.

DATA BUS OUTPUTS (ARINC 453 BUS) PROVIDE HARDWARE CONFIGURATION VERIFICATION, FAULT MONITORING AND RADAR TARGET DATA FOR DISPLAY.

[CONTINUED]

WRT-701XN RECEIVER TRANSMITTER (FIGURE 4)

AUXILIARY INPUTS:

HPA ON/OFF

RECORD GATE

AUXILIARY OUTPUTS; (* NASA PROCESSOR INPUTS)

* FIRST IF
* TRANSMIT SYNC
* 2ND RANGE SYNC
* 4 MHz CLOCK
* COHERENT REF OSCILLATOR

WRT XMIT PEAK POWER MONITOR

AUX SECOND IF STC

AUX SECOND IF RANGE VIDEO

AUX SECOND IF QUADRATURE (Q) RETURN

AUX SECOND IF IN-PHASE (I) RETURN

HPA POWER ENABLE

HPA STANDBY/OPERATE

HPA VIDEO GATE

HPA 777.7 MHz REFERENCE

HPA PHASE DETECTOR

HPA PEAK POWER MONITOR

GENERAL QUESTIONS AND ANSWERS

Q: SCOTT GRIFFITH (Allied Pilots Association) - In view of present FAA regulatory requirements, what economic incentives do the airlines have to explore new wind shear measurement technologies i.e., predictive and/or combined systems?

A: GUICE TINSLEY (FAA) - The expected benefit from predictive systems would be safety benefits and the expanded capabilities resulting from the detection of clear air turbulence. However, there is a long term economic benefit resulted from improved safety.

Q: FRANK DREW (Lockheed Austin Division) - Has the FAA committed to regard current reactive systems as compliant once predictive systems are real and affordable? If not, what kind of reaction time will the industry be given once predictive systems are real and affordable?

A: GUICE TINSLEY (FAA) - It is impossible to clearly forecast the future. However, based on past experience and assuming no catastrophic events that would require change of the wind shear equipment rule, both reactive and predictive systems are allowed and considered in compliance with the rule.

Q: ED LOCKE (Thermo Electron Technologies) - Will there be any new LIDAR device R & D funding available in '91 and '92 for better and cheaper LIDAR concepts?

A: ROLAND BOWLES (NASA Langley) - There is not likely to be any out-of-house funding. There is the possibility of in-house funding to accelerate the 2 micron work. We also would want to leverage that 2 micron work against space applications which is another significant need from a NASA perspective, other than just airborne wind shear detection.

Q: WALT OVEREND (Delta Airlines) - How are we to reconcile that all of the airline aircraft or a great majority will be equipped with reactive wind shear systems? For a fleet of 450 airplanes the cost will be, or is, $25 to $30 million dollars. Research efforts are now far behind the requirements established some 5 years ago.

A: ROLAND BOWLES (NASA Langley) - NASA can't reconcile that. You, the industry, perhaps have something to say about that. I think that the way to answer this is that the FAA in showing a great deal of flexibility and has decided to waiver the equipment rule for four U.S. carriers. Frank Tullo from Continental stated who those people were. That gives an additional period of time for the technology to mature, for you guys to get out and work and see what can be put in the marketplace that will satisfy a requirement for predictive wind shear detection. My feeling is that we've got 8 months to write a TSO for this equipment, if we ain't got it in 8 months, forget it. I think what we need to do is write an aviation system requirement and the sensor technology that fits will surface. It's a question of performance for acceptable cost. Our program in NASA is to get out and make those kinds of measurements, with systems that represent at least the class of technology that is on the horizon, and to provide that data uniformly to the industry and you make your decisions.

Q: PAT ADAMSON (Turbulence Prediction Systems) - Will you give me that Doppler radar is inferential and is not a direct measure of velocity?

79-80

A: ROLAND BOWLES (NASA Langley) - We've been arguing about this. I have made many comments that one of the things that was difficult to grasp was the inferential nature of an IR device in terms of estimating a wind. From my view point, the impedance match there is not very clear. But the physics now are supporting that kind of inferential measurement. It's got to be validated over a whole range of atmospheric conditions and other things. I'd like to get the radar and the laser people into this because I have often said that these are direct measurement devices and Pat argues that they are still inferential. You've got to understand pretty carefully the motion of the raindrop as it's forced by the wind. It has its own dynamics. And the aerosol, who knows what it's doing. Are pulse Doppler active measurement devices direct measurement devices or is there still some inferential nature to the characteristic of the measurement?

BRUCE MATTHEWS (Westinghouse) - I'm not going to exactly treat the question but I'm going to try to take it somewhere. The idea of inference may not be as direct as you've stated your question here. I think in a more general sense all sensors are going to make some inference about the hazards along the glide slope and that may be more the point. Roland was talking yesterday about the antenna beam being lifted as the airplane came down in altitude. That means that the radar is going to be pointing its main beam in a path near where the airplane is going to fly. It's going to infer what the hazard is along that glide slope from measurements made near the expected trajectory of the airplane. That will be an inference. Categorically that seems just as much an inference as the IR is making about a down draft inferred from temperature applying to the glide slope of the airplane.

UNKNOWN - If we understand the question right, the question is can we get a direct measure of the wind velocity. As the wind is coming down there is this a down draft which before it hits the ground, starts spreading out. Now, how long will it take before the rain drops pick up the velocity of the wind? We did some studies that showed that the time constant was of the order of 2 or 3 seconds. So the rain drops are following the wind velocity very closely. So based on that, I would say that the radar would give a direct measure.

PAT ADAMSON (Turbulence Prediction Systems) - Not to carry this too far, but with Doppler you've got the size of the volumetric sample, the pulse repetition frequency which determines the aliasing, and the turbulence or the vortex within the bin that's measured. I'm not saying it's not a good estimate, I don't mean that and I haven't argued that at all. But it is by no means a direct measurement of the velocity of the winds. It's a mean estimate of the spectral distribution returned to the receiver. Over most cases that's probably pretty good. I have a real problem with direct measurement with any remote sensor. It is not a direct measurement. It's an inference based on some physical principle. There are a lot of errors as we saw on the talk just a little while ago. As you get low signal to noise those inferences and those assumptions tend to go down.

Q: RICHARD DOBINSKY (Sky Council) - There are three basic techniques that are being discussed to detect wind shear; radiometric techniques, laser and radar. Are there any other techniques, and if so elaborate on these.

A: ROLAND BOWLES (NASA Langley) - There has been work done by the French on sound detection and ranging, large low frequency, infra-sound. We've done some work at the center on infra-sound. We can sit at Langley Research Center and listen to the shuttle take off at the Cape using low frequency sound. I think that is beyond the scope of what we're trying to do in our program. Typically you would think they would be ground based, so it's FAA's problem.

Q: RICHARD DOBINSKY (Sky Council) - Please summarize the trade off comparisons, strengths and weaknesses of each of the three detection techniques.

A: ROLAND BOWLES (NASA Langley) - That's what the conference has been all about over the last several years. My view is they are all going to work to some degree. I think some circumstantial evidence is now being developed along those lines. If things go according to the plan Mike Lewis laid out, we're going to have a lot to say about these at the next conference. I would like to point out one other thing. If you listened carefully you could see a little bit of an anomaly in some of the questions I was raising with regard to reactive systems. We raise questions about wether the people who operate them and have certified them really have a convincing case that can be made about their validity. That's an open question. I do believe it is possible to engineer devices and that the industry has engineered devices that make very good energy change measurement systems for airplanes. Reasonable men can then debate at what level of energy change we annunciate alerts and how do we trade it off. In NASA's program, we're not building a reactive warning system, we're building a reactive measurement system for airplane energy change that will become a standard by which we try to assess, to some degree, the validity of our forward look devices. It seems to me that it is imperative in our program that we establish that what a forward look sensor sees at time t the airplane will experience at $t + \tau$ seconds, where τ is positive. If not, the whole concept of prediction is flawed. You would have to make decisions on information that would not be a reliable indicator or trend setter for what would happen to you if you elected to continue. It's just fundamental. I think the Orlando experiment is the first ever a demonstration that that hypothesis may be true for one particular electro-optical technique. That's a winner. In other words, reactive systems when properly implemented should satisfy Newton's law and I'm going to stay with Newton. He hasn't been wrong yet if you treat him right.

Q: RICHARD DOBINSKY (Sky Council) - Can you choose an optimum configuration or technique to focus R & D upon?

A: ROLAND BOWLES (NASA Langley) - In other words, what will be NASA's criteria to reject a technology. Within the time and money we've got to work the program, if it don't work we're going to reject it. It's got to provide measurement performance that at least satisfies what we would consider a success criteria for measurement performance. I think all three of these technologies are going to work to some degree. There is always going to points on the envelope where you can fool the instrument perhaps. But then that raises the question of how many missed alert are too much and how many nuisance alerts are too much? I think an example for us to learn from is the trials and tribulations that the TDWR guys have gone through. They've done a remarkable job of sorting that out. Look at what they're doing, they're getting out in the field year in and year out and collecting data. It's the only way you can refine answers to those kinds of questions. You've got to get out and collect data.

Q: SUSAN KIM (Boeing) - With regards to the extension obtained requested by the four airlines what happens if when the extension period is up, the new forward looking technology is not defined sufficiently to equip those aircraft which don't have wind shear alerting systems? (Will they then be required to equip with reactive systems while the forward looking effort continues?)

A: HERB SCHLICKENMAIER (FAA) - As I understand it, if at the end of the evaluation period there does not seem to be "sufficient progress", then the program for that wavered airline turns into a reactive schedule starting up as if it happened on that date.

ROLAND BOWLES (NASA Langley) - I would like to make a comment on that. Given the current cost of money, that policy could save somebody a fair amount of bucks. One might wonder why some or all of the airlines didn't leap in.

Q: MIKE TAYLOR (Boeing) - Can the airborne Doppler radar distinguish between a microburst event and a tornado?

A: STEVE CAMPBELL (MIT Lincoln Laboratory) - It is worth noting that the TDWR in our test bed and I believe also the Mile High radar, have been running a prototype tornado vortex signature algorithm. One problem you have running that is, of course, that you have very few data points. There were some tornadoes out in Denver in 1987 or '88. In fact, as one of the microburst algorithm developers I was proud to announce that we detected some of those tornadoes as microbursts as well. I would think you should be able to do it with a technique similar to what's done for the TVS algorithm.

UNKNOWN - From a cockpit perspective, a tornado has a classic signature on a weather radar. I don't think that Doppler is really necessary for that, assuming we keep weather radar in the aircraft.

ROLAND BOWLES (NASA Langley) - We should never take weather radar out of the cockpit, I'll agree with you there.

CLOSING REMARKS

ROLAND BOWLES (NASA Langley) - There is a lot of sensitivity about stand alone forward look versus not stand alone. My feeling is, and I've always said it, many people have said it, and I've heard myself say it many times, "reactive systems technology is non throw away". Policy gets in the question here at some point. But it's non throw away technology. That doesn't mean that there may not end up a predictive technology that may stand alone. What gets involved here is corporate policy, airline operations, how industry wants to respond to it, a lot of different things. I think progress is being made in all three areas of the sensor technology. I think what can be done by an appropriate synthesis of the ground based technology, as LLWAS and TDWR gets integrated, and how we can move those kinds of products to the flight deck to the benefit of both operations and safety, the prospects are very bright in that. I think the point is our task is simple for the next year. We're going to put these sensors on. We've decided what they are. The hardware is being cut. This is the last big funding bulge in our program because hardware tails off next year and then it's mainly operating the airplane, making measurements and hopefully doing a thorough analysis and presentation of results to you, the industry. The course is set for us, a lot of work to be done on the NASA side. I still would feel that somehow a process has to be put together to really write down the aviation system requirement for predictive systems. We can't linger on that one. It's got to be done here in the next 8 to 10 months.

I appreciate all of you coming. I think it has been a good conference. By the way there were 188 people cumulative, not maybe 188 in a room at any one given instant, but most of them, some of them stayed in the bar a lot. This has been a real good turn out. It's been the largest turn out of any of these conferences to date. I think the one thing that encourages me is that at the first meeting a few years ago, NASA and the FAA were doing all the talking by and large. Now we're to the point where, if you looked at the agenda carefully, there was a 50/50 split between industry speaking and other government agencies speaking and people like NCAR and Lincoln Labs. Perhaps next time it will even be dominated by an industry response. The problem is really one where we owe you technical answers to well understood and well posed technical questions. But eventually its marketplace dynamics and manufacturers willing to bite the bullet , take the risk, build and certify, that's going to do it.

PAT ADAMSON (Turbulence Prediction Systems) - From the industry standpoint, I just want to reemphasize that if we're not active we will not have predictive sensors. It's going to take more than the government side or the NASA side or the FAA side. It's going to take the people that are in this room and others to not go home and forget and say, well somebody else will deal with it. It needs to be dealt with if you want predictive sensors. The product is driven by whether you can sell it. The retrofit market is one of the incentives for people like myself and others to get into this thing. So we've got to get after this problem. Not just not talk about it but do something about it.

ROLAND BOWLES (NASA Langley) - One final precaution here. You know we've declared victory at least twice or so on this problem and it always comes back. We ought to be very careful here, with the capital investment we've all made in this, not to declare victory prematurely and walk away from it. I think that this time we ought to have some answers that ought to stand the test of time.

HERB SCHLICKENMAIER (FAA) - I harken back to when I was one of the advisors in the National Academy of Sciences review of low altitude wind shear, coming down to a place in Tidewater, Virginia, where they kind of know something about airplanes, and

85.56

talking with an expert panel of people on the airplane side of the problem. There were heads of research organizations that were giggling at the concept in 1982 and '83 of remotely detecting a hazardous wind shear phenomena. I'll humbly submit there was still the question on the table of what does hazardous mean. There were questions about the size, there were questions about the concept. A program was borne in '86 where we finally sat down and decided to just answer the question that the National Research Council posed. If radar won't work then we'll write that up. Over the course of time we were fortunate enough to expand our horizon and take a look at the technologies available from LIDAR and infrared. We are now to the point where the last question in a conference on airborne wind shear detection technology is not will, but can the airborne Doppler radar distinguish between a microburst and a tornado. There's an inference there that we've already solved the problem. We've come a tremendous way and as Roland has indicated there is more to go. Yes, I have been associated with other programs where success was declared early and came back to have to eat those words. You're going to make this work. It's a safety program that I think we can pull the national resources together to address. And, barring certain shortfalls in travel funds I trust that we and the rest of the FAA will be able to partake wholeheartedly in this very exciting and last venture in aviation safety. Thank you very much.

PAUL KELLY (21st Century Technology) - Herb, I think I speak for everybody when I say we'd like to ask you and Roland to communicate to your respective chains of command the appreciation and gratitude of all of us who have attended this conference. We have been real impressed with the material that's been presented and we want you to know that you guys, in our opinion, did a very good job. We want also not to forget all your staff and the Bionetics personnel who assisted you. We are really very grateful and you are to be wholeheartedly commended.

Appendix - List of Attendees

89-96

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16. Abstract

The Third Combined Manufacturers' and Technologists' Conference was hosted jointly by NASA Langley Research Center (LaRC) and the Federal Aviation Administration (FAA) in Hampton, Virginia, on October 16-18, 1990. The meeting was co-chaired by Dr. Roland L. Bowles of LaRC and Herbert Schlickenmaier of the FAA. The purpose of the meeting was to transfer significant ongoing results of the NASA/FAA joint Airborne Wind Shear Program to the technical industry and to pose problems of current concern to the combined group. It also provided a forum for manufacturers to review forward-look technology concepts and for technologists to gain an understanding of the problems encountered by the manufacturers during the development of airborne equipment and the FAA certification requirements. The present document has been compiled to record the essence of the technology updates and discussions which followed each.

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