Session VI. Airborne Doppler Radar / NASA

NASA Experimental Airborne Doppler Radar and Real Time Processor for Wind Shear Detection

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Experimental Radar System Capabilities

o Independent Data Frames 128 Pulse Repetition Periods per Frame

o Selectable Transmitter Parameters
- o PRF (9581, 4791, 3755, 2395, 1198 Hz)
- o Pulse Width (1, 2, 4, or 8 µs)
- o Dual X-Band Transmit Frequencies

o Selectable Antenna Parameters
- o Scan Pattern (az, el, az/el)
- o Scan Rate (3 Frames/1.5°)

479

Experimental Radar System Capabilities
Continued

o   Independent AGC for each Range Bin (>60 dB)

o   Fast I.F. Gain Control (<0.5 µs)

o   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)

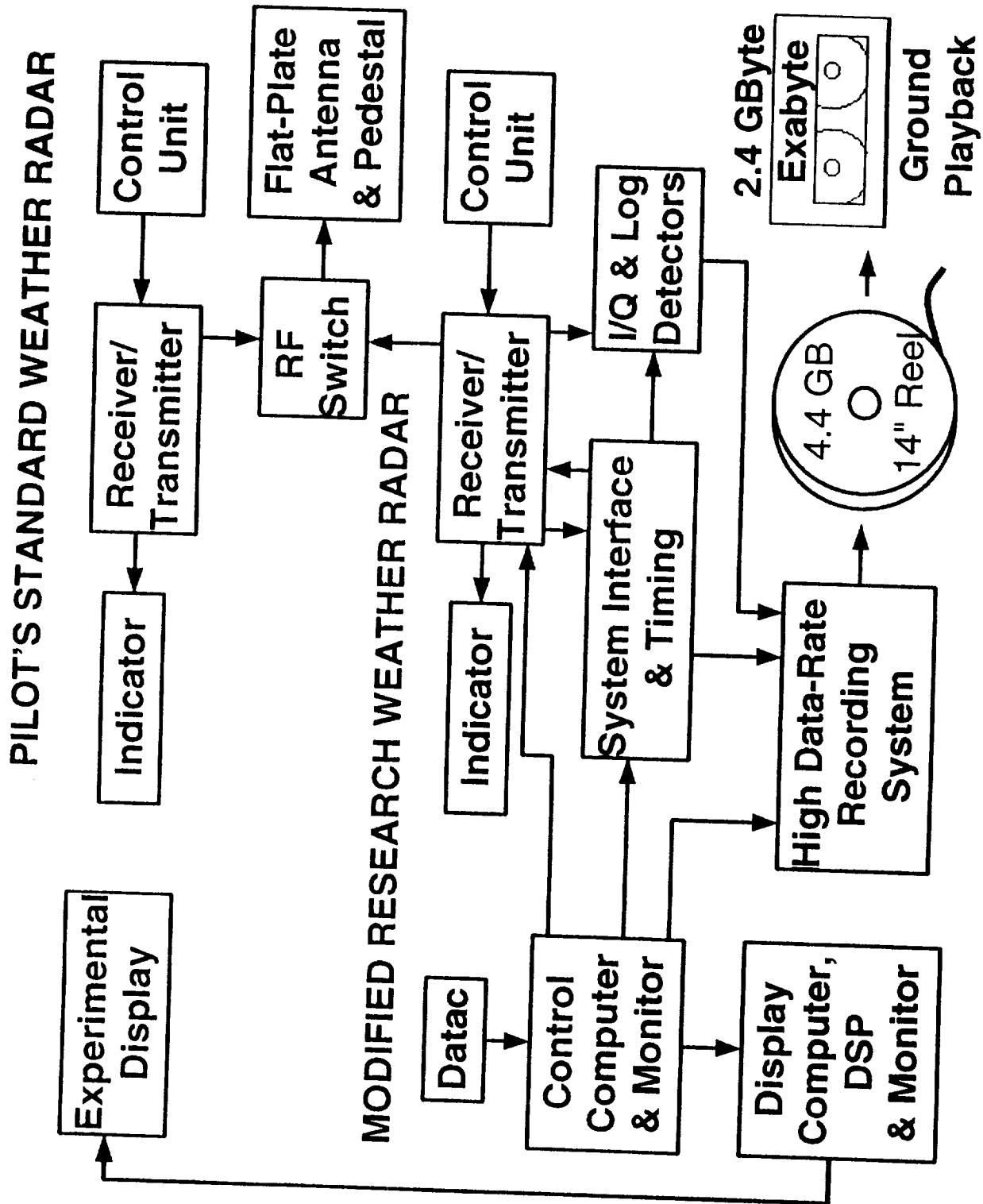# Experimental Radar System Capabilities

Continued

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

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

Experimental Radar System Block Diagram

PILOT'S STANDARD WEATHER RADAR

Control Unit

Flat-Plate Antenna & Pedestal

Receiver/Transmitter

RF Switch

Indicator

Experimental Display

MODIFIED RESEARCH WEATHER RADAR

Control Unit

Receiver/Transmitter

I/Q & Log Detectors

2.4 GByte Exabyte

Ground Playback

System Interface & Timing

4.4 GB

14" Reel

Indicator

High Data-Rate Recording System

Datac

Control Computer & Monitor

Display Computer, DSP & Monitor
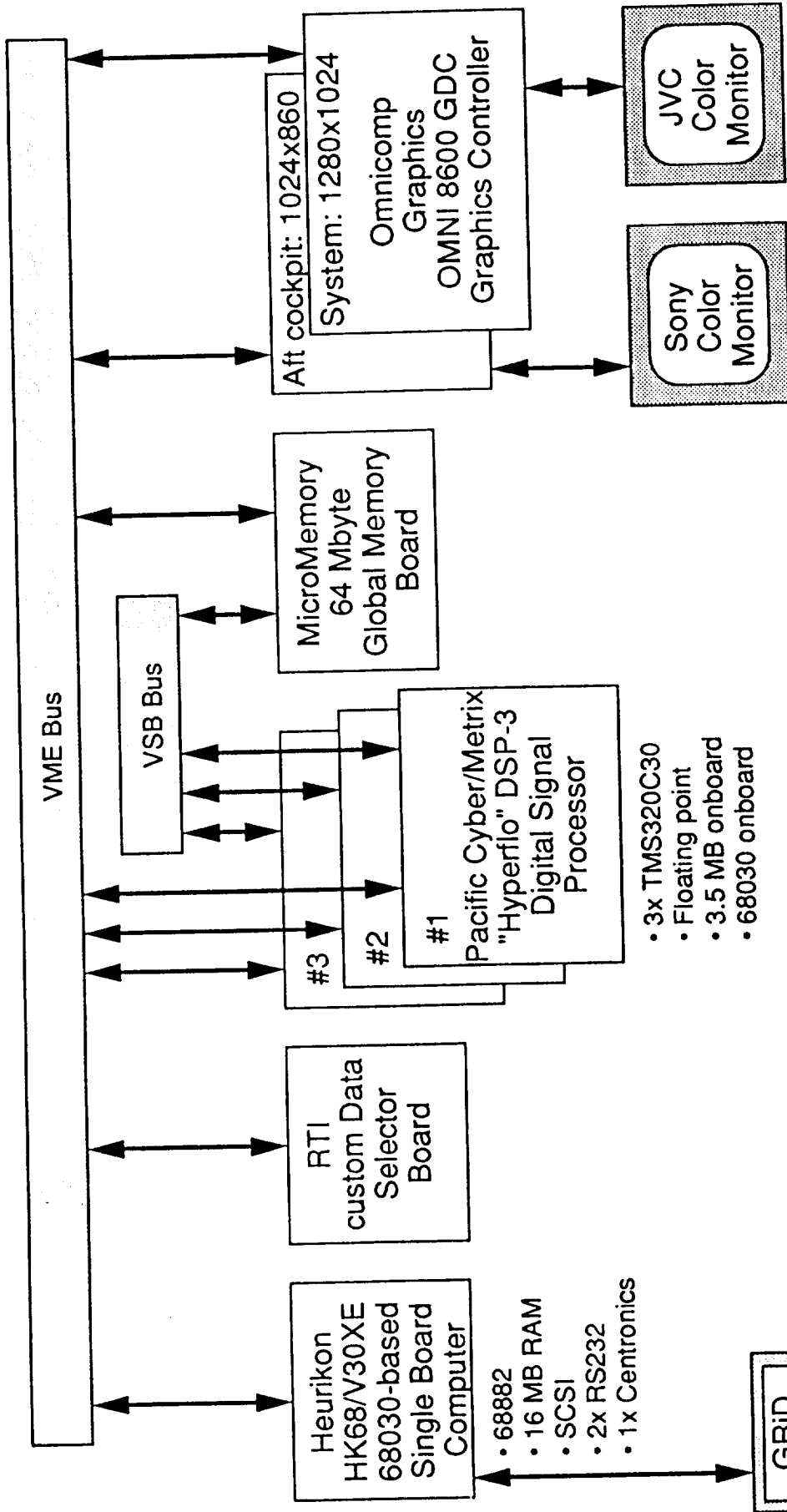
482

Wind shear Radar Signal and Data Processor (WRSDP)

o Developed under contract to NASA Langley Antenna and Microwave Research Branch (AMRB) by Research Triangle Institute (RTI) with sub-contractor Georgia Tech Research Institute (GTRI)

o VME-bus based computer, Motorola 68030 host running the OS-9 real time operating system

o Three Pacific Cyber/Metrix DSP-3 boards each containing 3 TI TMS320C30 processors running at 33 MHz (Total mfg. rating 300 MFLOPS)

Wind shear Radar Signal and Data Processor (WRSDP)

continued

- o Two high resolution graphics boards and monitors, hard and floppy disk drives, 64 MByte VME/VSB bus memory board

- o Custom data selector board designed by RTI to allow use of data from radar, tape, or on-board simulation

- o GRiD 386 laptop computer, with separate keypad, for system console

WRSDP HARDWARE ARCHITECTURE

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VME Bus
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Omnicomp Graphics OMNI 8600 GDC Graphics Controller
Aft cockpit: 1024x860
System: 1280x1024

JVC Color Monitor

Sony Color Monitor

MicroMemory 64 Mbyte Global Memory Board

VSB Bus

Pacific Cyber/Metrix "Hyperflo" DSP-3 Digital Signal Processor
#1
#2
#3
- 3x TMS320C30
- Floating point
- 3.5 MB onboard
- 68030 onboard

RTI custom Data Selector Board

Heurikon HK68/V30XE 68030-based Single Board Computer
- 68882
- 16 MB RAM
- SCSI
- 2x RS232
- 1x Centronics

GRiD laptop
- 80386SX
- 2 MB RAM
- 640x480 LCD
- 60 MB hard drive

Additional hardware features:
- 390 MB system hard disk
- 1.4 MB 3.5" floppy disk
- MuPAC VME enclosure
  - 12 slots
  - 500 W power supply

485

WRSDP System Design Goals

o Flexible research tool for in-flight display and post-flight data analysis

o Implement signal processing algorithms for real-time Doppler mean and variance estimation

o Provide additional algorithms to calculate received power and signal spectra

o Implement hazard detection, tracking, and alert algorithms

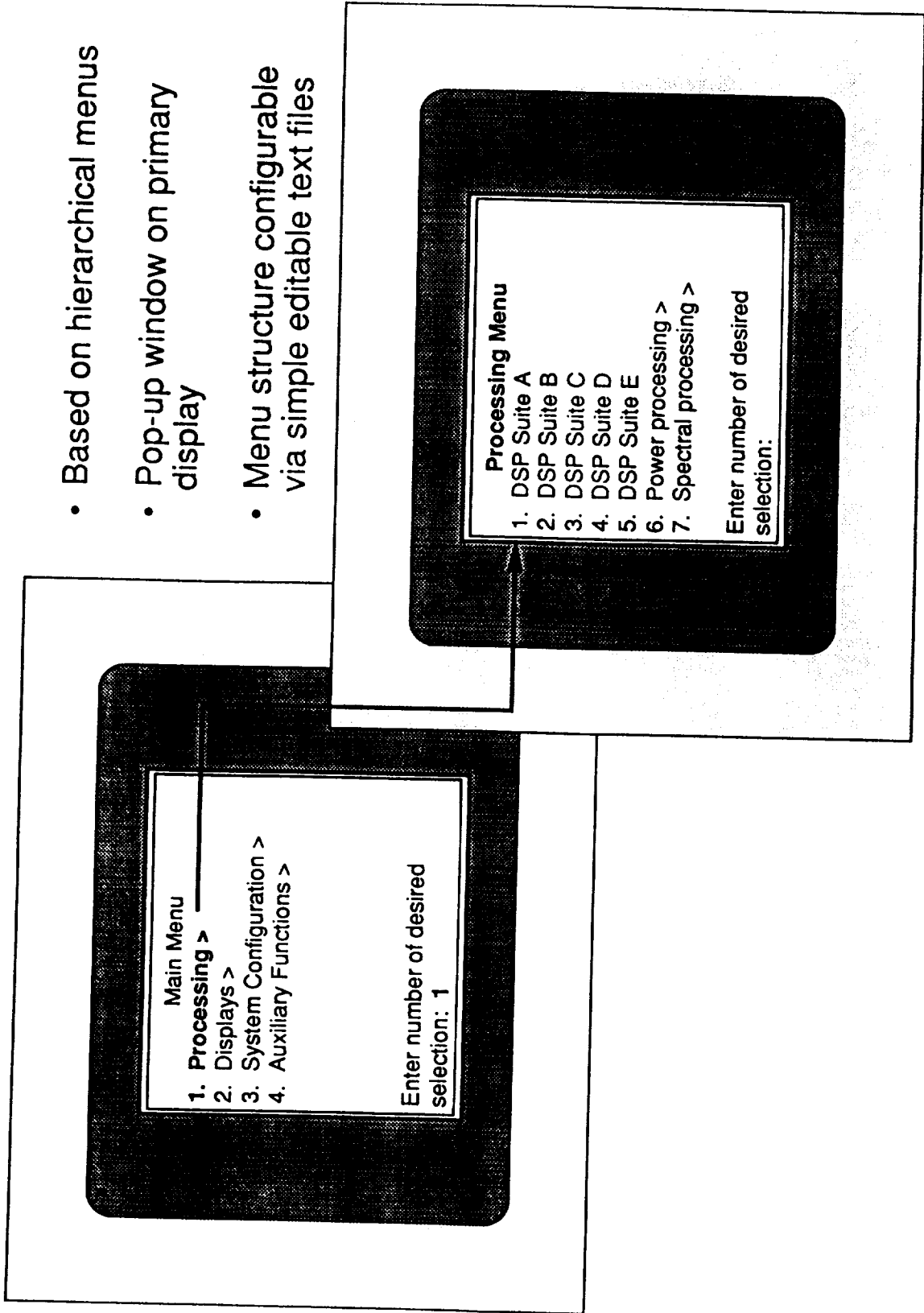o Support up to 6 simultaneous displays on 2 monitors

C-6

WRSDP System Design Goals

continued

o Provide a convenient, configurable, menu driven user interface

o Use flexible, modular software design to support development of new algorithms and displays

o Second radar/DSP system based in mobile van
   o Quick look post-flight analysis of recorded flight data
   o Investigation of interference problems between the two radars
   o Collection of weather data for comparison with aircraft data
   o Development platform to implement and test hardware and software modifications
   o "Live" spares for the airborne radar

487

USER INTERFACE

- Based on hierarchical menus

- Pop-up window on primary display

- Menu structure configurable via simple editable text files

Main Menu
1. Processing >
2. Displays >
3. System Configuration >
4. Auxiliary Functions >

Enter number of desired selection: 1

Processing Menu
1. DSP Suite A
2. DSP Suite B
3. DSP Suite C
4. DSP Suite D
5. DSP Suite E
6. Power processing >
7. Spectral processing >

Enter number of desired selection:

488

DSP Software Development Tools

o **On Sun Workstation**

  o TMS320C30 C Compiler

  o SPOX DSP Library

  o TMS320C30 Simulator

  o EMACS and vi editors

  o Revision Control System (RCS)

  o TCP/IP, NFS, Terminal Emulation, printing services

o **On Heurikon 68030 Host**

  o PC/M DSPdebug utility

OS-9 Software Development Tools

- On Heurikon 68030 Host

  - Microware OS-9 Operating System and Utilities

  - uMACS editor

  - C and gcc

  - Make utility

  - Source and system debuggers

  - TCP/IP and NFS

  - Absoft FORTRAN

WRSDP Digital Signal Processing

o Basic purpose of DSP suites is the estimation of Doppler velocity mean and variance in each range-azimuth resolution cell

o Choice of 4 different sets of DSP algorithms ("suites") currently provided for real-time use in performing these estimates

o Other algorithms will be developed for post-flight analysis of data

491

WRSDP Digital Signal Processing
Continued

o The DSP suites are formed from various combinations of:

o **Clutter filters**

Time Domain - FIR or IIR
Frequency Domain - Line Editing

o **Spectrum Estimators**

Fourier Transform, Autoregressive model, or none

o **Frequency Estimators**

Time-domain pulse pair, frequency domain pulse pair, first moment

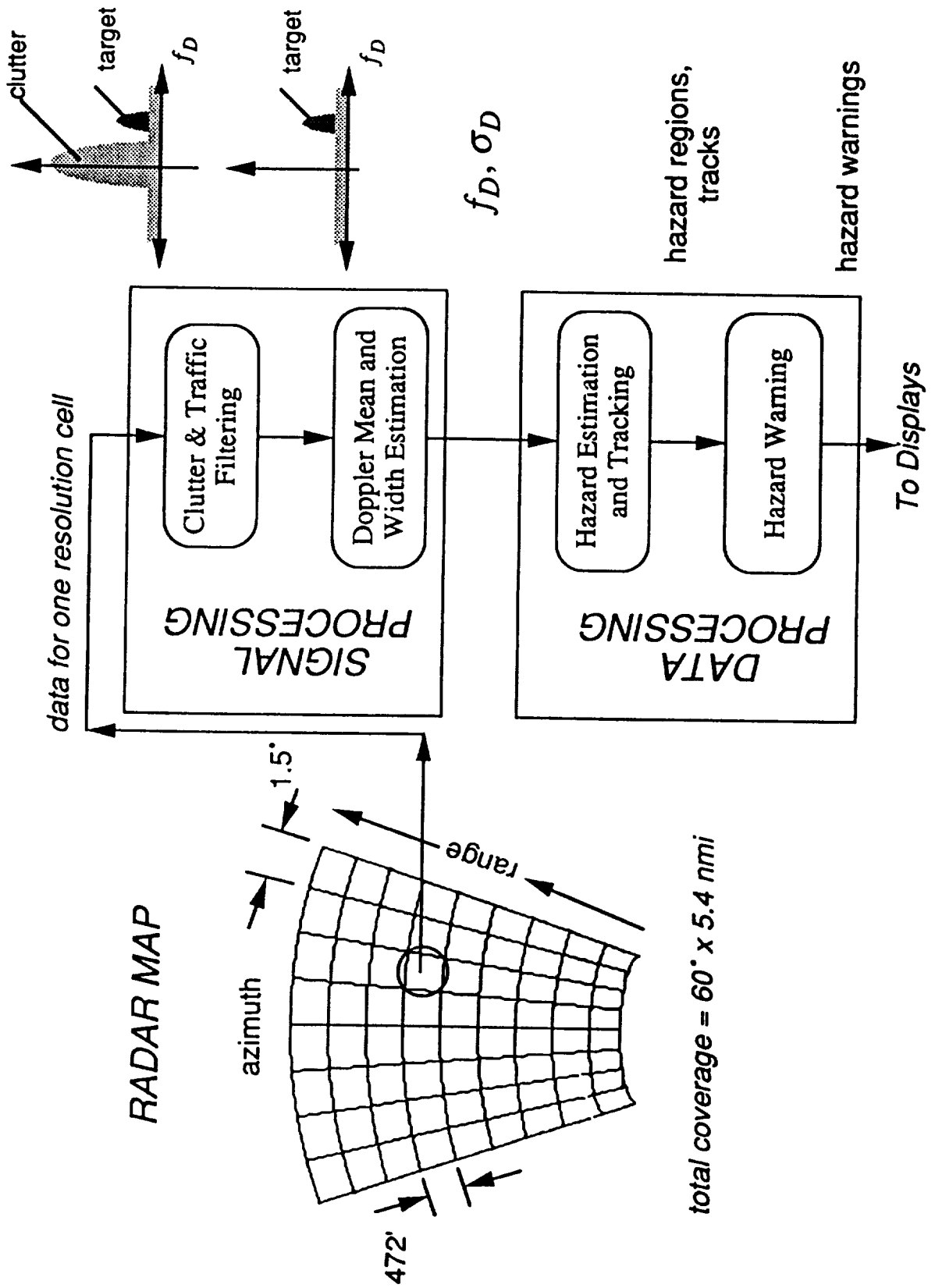| SUITE	FILTER			SPECTRUM ESTIMATOR			FREQUENCY ESTIMATOR		
	FIR	IIR	LINE EDIT	NONE	FOURIER	AR	Time domain pulse pair	Freq. domain pulse pair	First moment
A		X		X			X		
B		X	X		X				X
C	X			X	X		X		
D		X	X		X			X	
E		X	X			X			X

493

WRSDP Display Operational Modes

o Derived Velocity versus Range along range line

o Received Power versus Range along range line, in dBm or dBz

o FFT of selected Range Bins across 1 frame of 128 pulses

o Color map of velocity/range over full azimuth scan

o Color maps of power/range over full azimuth scan

o Color map of hazard/range over full azimuth scan with wind shear tracking and alarm algorithms
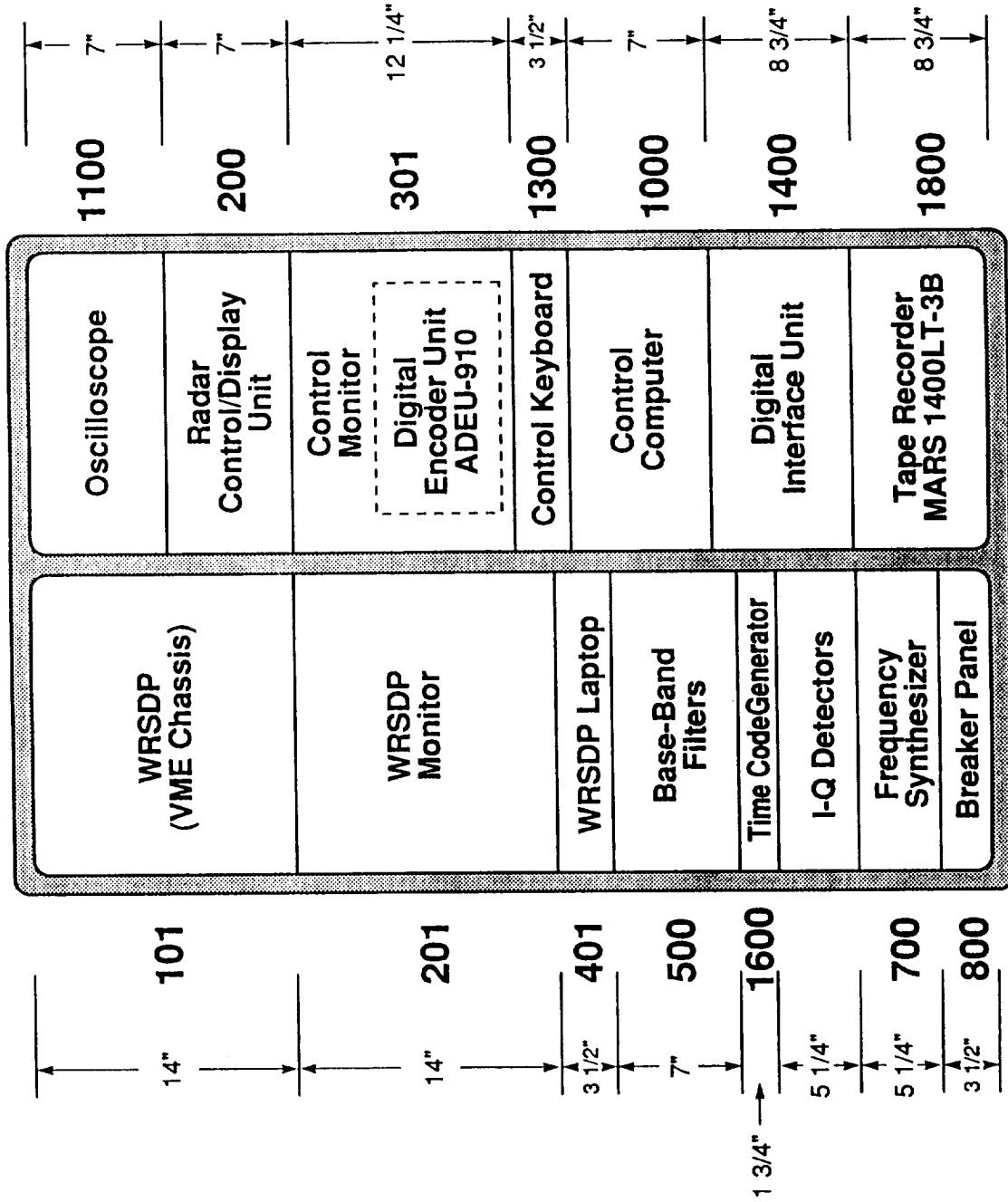
494

WRSDP Division of Functions

o **Signal Processing - on DSP boards**
  - o Test signal injection
  - o Data flow and process control
  - o DSP algorithm suites

o **Data Processing - 68030 host**
  - o User interface menu system
  - o Hazard detection and tracking
  - o Graphics calculations
  - o Diagnostics, start-up, load DSP images, tape control, etc.

STRUCTURE OF WRSDP SIGNAL & DATA PROCESSING ALGORITHMS

clutter

target

f_D

target

f_D

f_D, σ_D

hazard regions, tracks

hazard warnings

data for one resolution cell

SIGNAL PROCESSING

Clutter & Traffic Filtering

Doppler Mean and Width Estimation

DATA PROCESSING

Hazard Estimation and Tracking

Hazard Warning

To Displays

RADAR MAP

azimuth

1.5°

range

472'

total coverage = 60° x 5.4 nmi

WINDSHEAR RADAR FLIGHT EXPERIMENT

Aircraft Console Equipment Arrangement

Unit	Measurement
1100	7"
200	7"
301	12 1/4"
1300	3 1/2"
1000	7"
1400	8 3/4"
1800	8 3/4"

Top row units:
- Oscilloscope (1100)
- Radar Control/Display Unit (200)
- Control Monitor (301)
- Digital Encoder Unit ADEU-910
- Control Keyboard (1300)
- Control Computer (1000)
- Digital Interface Unit (1400)
- Tape Recorder MARS 1400LT-3B (1800)

Bottom row units:
- WRSDP (VME Chassis) (101) — 14"
- WRSDP Monitor (201) — 14"
- WRSDP Laptop (401) — 3 1/2"
- Base-Band Filters (500) — 7"
- Time Code Generator (1600) — 1 3/4"
- I-Q Detectors (700) — 5 1/4"
- Frequency Synthesizer — 5 1/4"
- Breaker Panel (800) — 3 1/2"

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Summary

o Airborne Wind Shear Radar System was flown in 1991 and successfully collected clutter, microburst and gust front data

o WRSDP system has been tested and confirmed to be operational in laboratory with 4 algorithm suites implemented

o Airborne Wind Shear Radar/WRSDP system currently being installed on NASA 737 for 1992 flight tests

o Second system for Van/Playback/Quick-look being assembled and tested in laboratory