SYNTHETIC APERTURE RADAR SIGNAL PROCESSING: TRENDS AND TECHNOLOGIES

VEXCEL
CORPORATION

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presented at the
3rd SPACEBORNE IMAGING RADAR SYMPOSIUM

JET PROPULSION LABORATORY
PASADENA, CA
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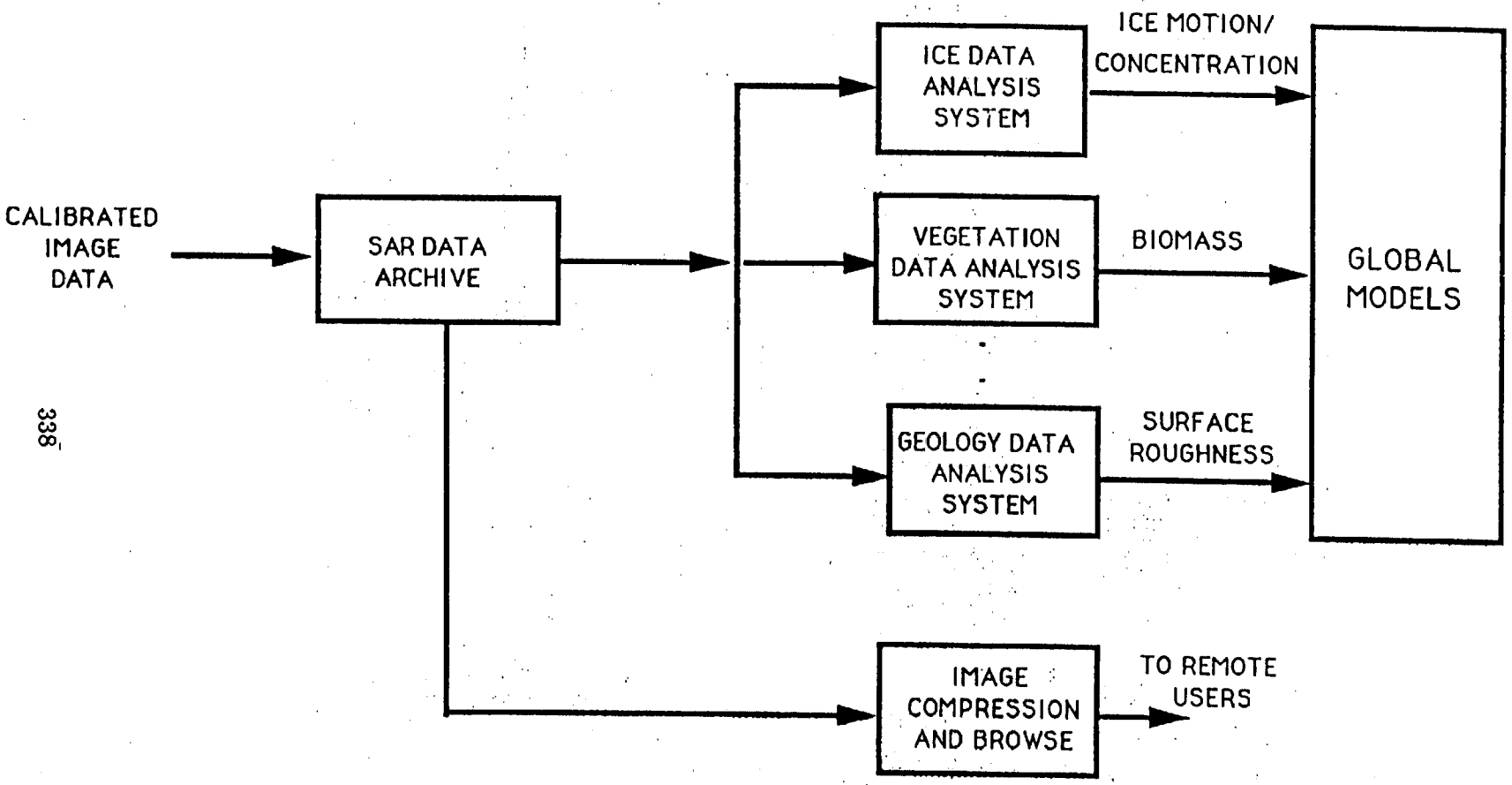
OVERVIEW OF SAR PROCESSING

SAR DATA SYSTEM OVERVIEW



DATA UTILIZATION AND INFORMATION EXTRACTION SYSTEM

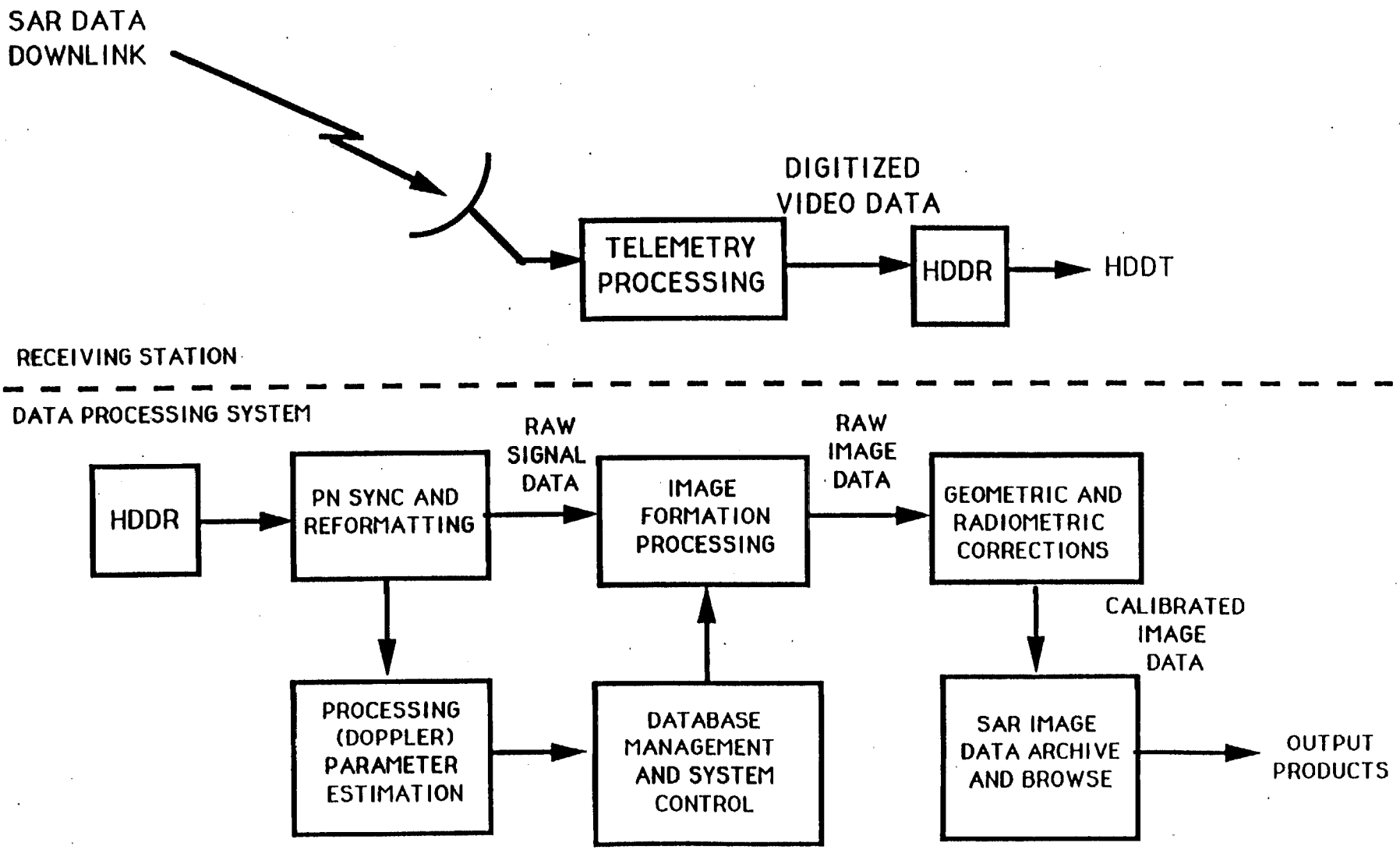
SAR CORRELATOR: TRENDS AND TECHNOLOGIES

OUTLINE

- OVERVIEW
  - SAR GROUND DATA SYSTEM
  - SAR SIGNAL PROCESSING ALGORITHMS
  - SAR CORRELATOR ARCHITECTURES
- CURRENT OPERATIONAL SYSTEM IMPLEMENTATIONS
  - ARCHITECTURES
  - ALGORITHMS
- SUMMARY
  - CURRENT, FUTURE TRENDS

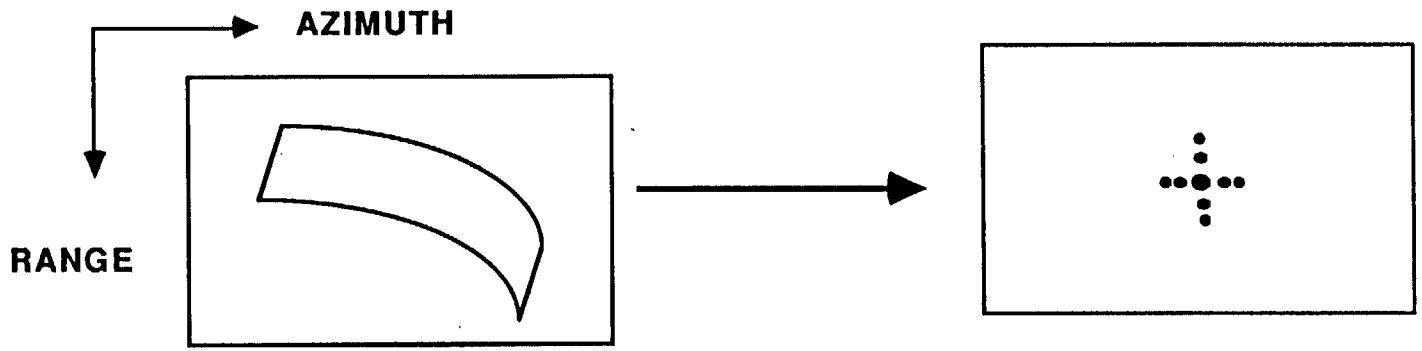
OVERVIEW OF SAR PROCESSING

SAR DATA SYSTEM OVERVIEW

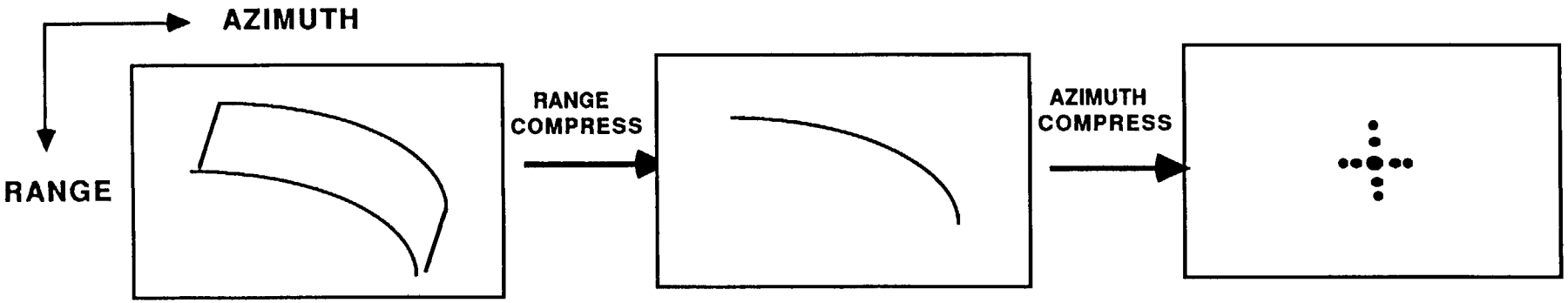


SAR CORRELATOR: TRENDS AND TECHNOLOGY

SAR PROCESSOR ALGORITHM OVERVIEW



APPROACH 1: APPPLY 2-D FILTER TO COMPENSATE FOR PHASE DISPERSION



APPROACH 2: APPLY TWO 1-D FILTERS FORMING A RANGE COMPRESSED IMAGE

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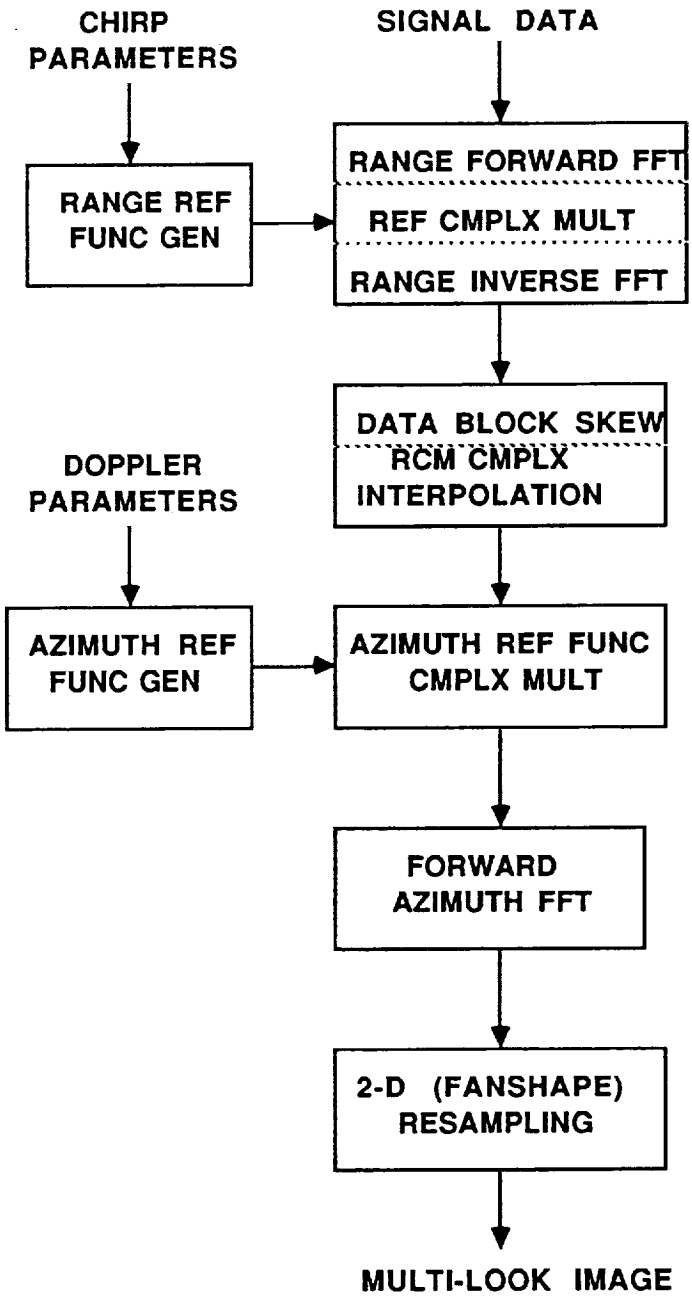
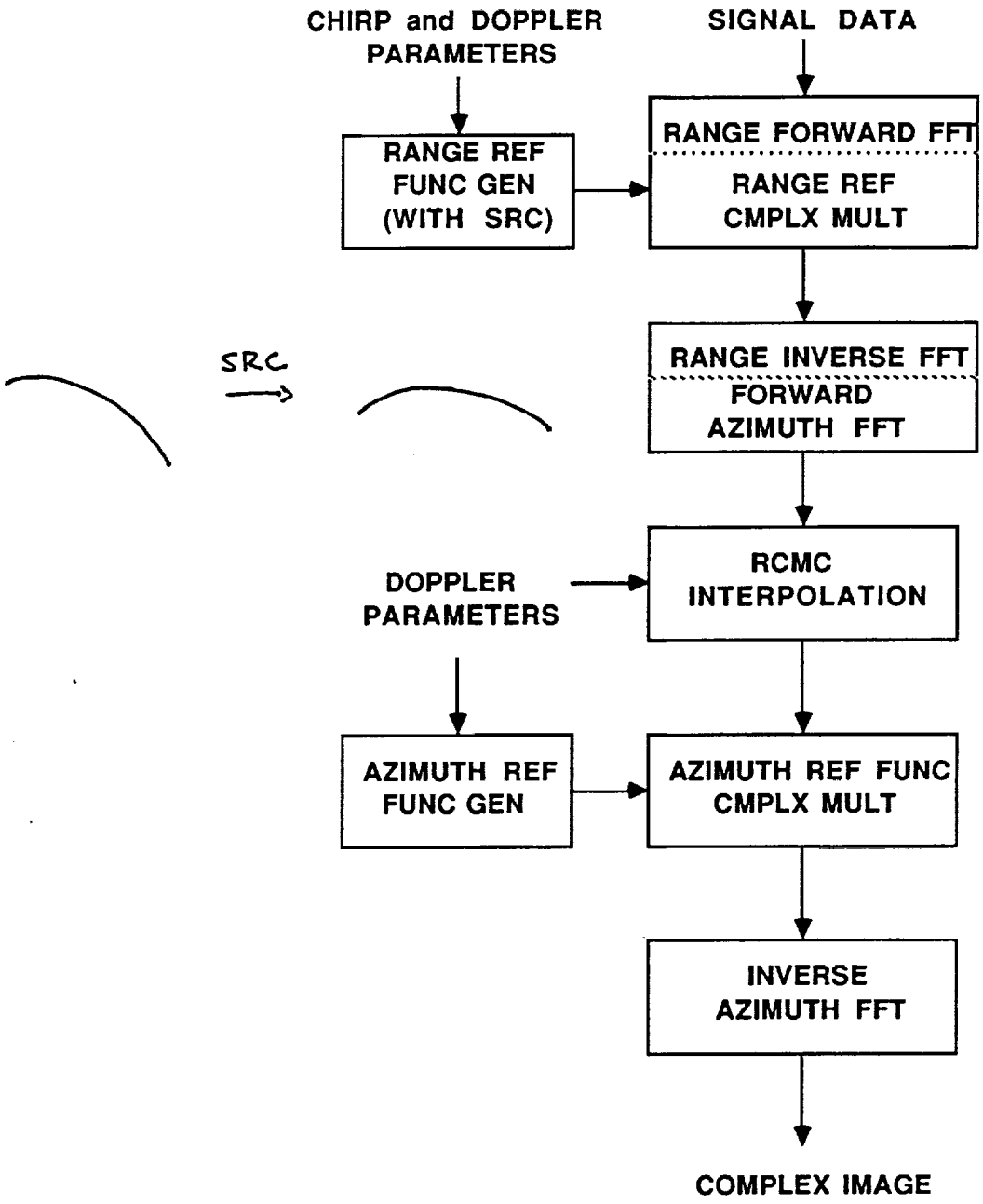
ALGORITHM OVERVIEW

- SPECTRAL ANALYSIS ALGORITHMS
  - COMPUTATIONALLY EFFICIENT, GOOD IMAGE QUALITY FOR SMALL TIME-BANDWIDTH PRODUCTS, CANNOT ACHIEVE FULL AZIMUTH RESOLUTION, VARIABLE SNR ACROSS IMAGE BLOCK
  - SPECAN (DERAMP/FFT): SCANSAR, BURST MODE RADARS
  - POLAR ALGORITHM: MILITARY APPLICATIONS, HIGH SQUINT, SMALL PATCH
- RANGE/DOPPLER ALGORITHMS
  - FULL AZIMUTH RESOLUTION, GOOD IMAGE QUALITY FOR MODERATE SQUINT, PROVEN ALGORITHM FOR SPACEBORNE SAR, EASY PREPROC AND MOCOMP, POOR PERFORMANCE ON HIGH SQUINT AND HIGH RESOLUTION SAR
  - SECONDARY RAGE COMPRESSION (SRC): BROADSIDE, STRIP IMAGERS
  - SQUINT IMAGING MODE (SIM): STRIP IMAGERS SQUINT UP TO 20 DEGREES
- 2D TRANSFORM (WAVE DOMAIN) ALGORITHMS
  - BEST APPROX, EXCELLENT PHASE FIDELITY, LITTLE OR NO INTERPOLATION, UNPROVED IN OPERATIONAL SYSTEMS, DIFFICULT PREPROC AND MOCOMP, APPLICATION IN INTERFEROMETRY AND POLARIMETRY
  - WAVE EQUATION: HIGH SQUINT (75 DEGREES), PHASE PRESERVING
  - CHIRP SCALING: REQUIRES LINEAR FM CHIRP, NO INTERPOLATION

SPECAN ALGORITHM FLOWCHART



RANGE/DOPPLER ALGORITHM FLOWCHART
WITH SECONDARY RANGE COMPRESSION (SRC)



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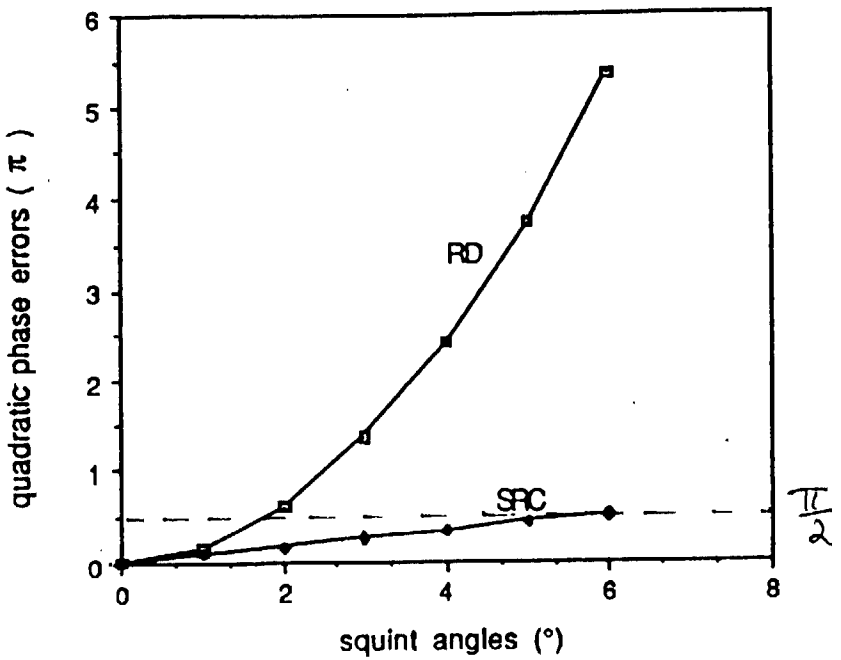
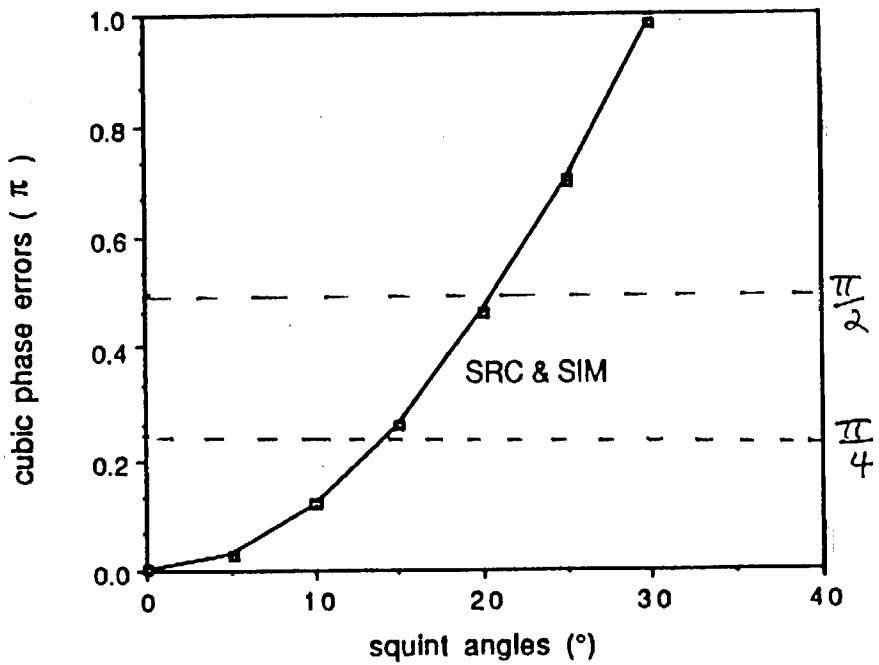
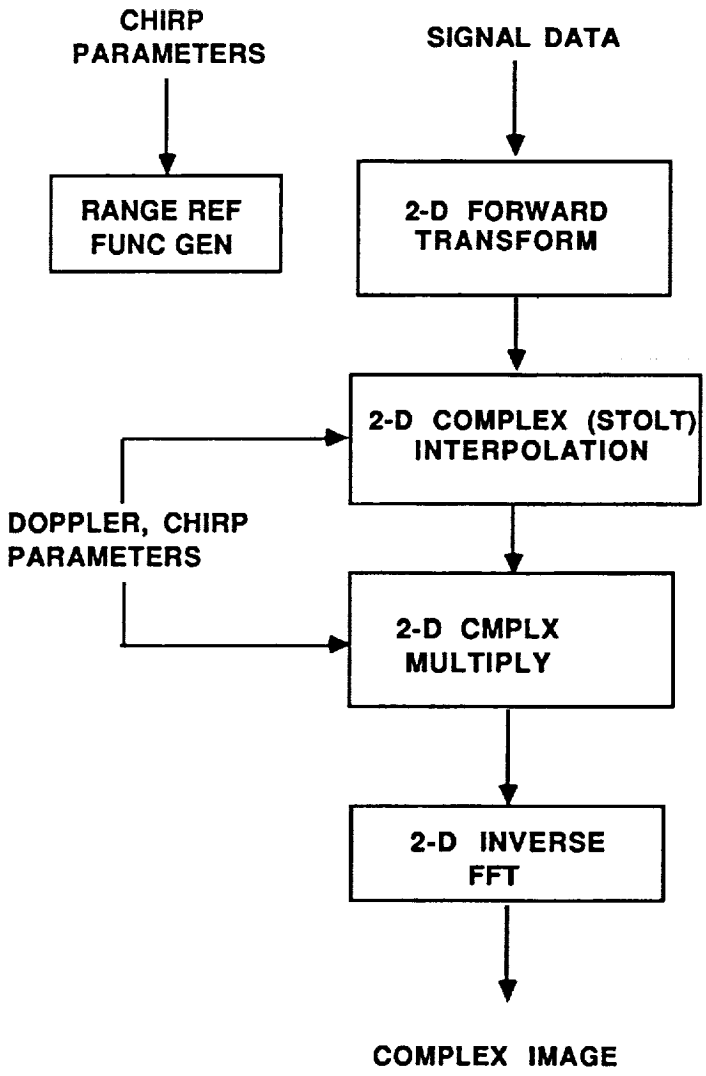
RANGE DOPPLER ALGORITHM PERFORMANCE





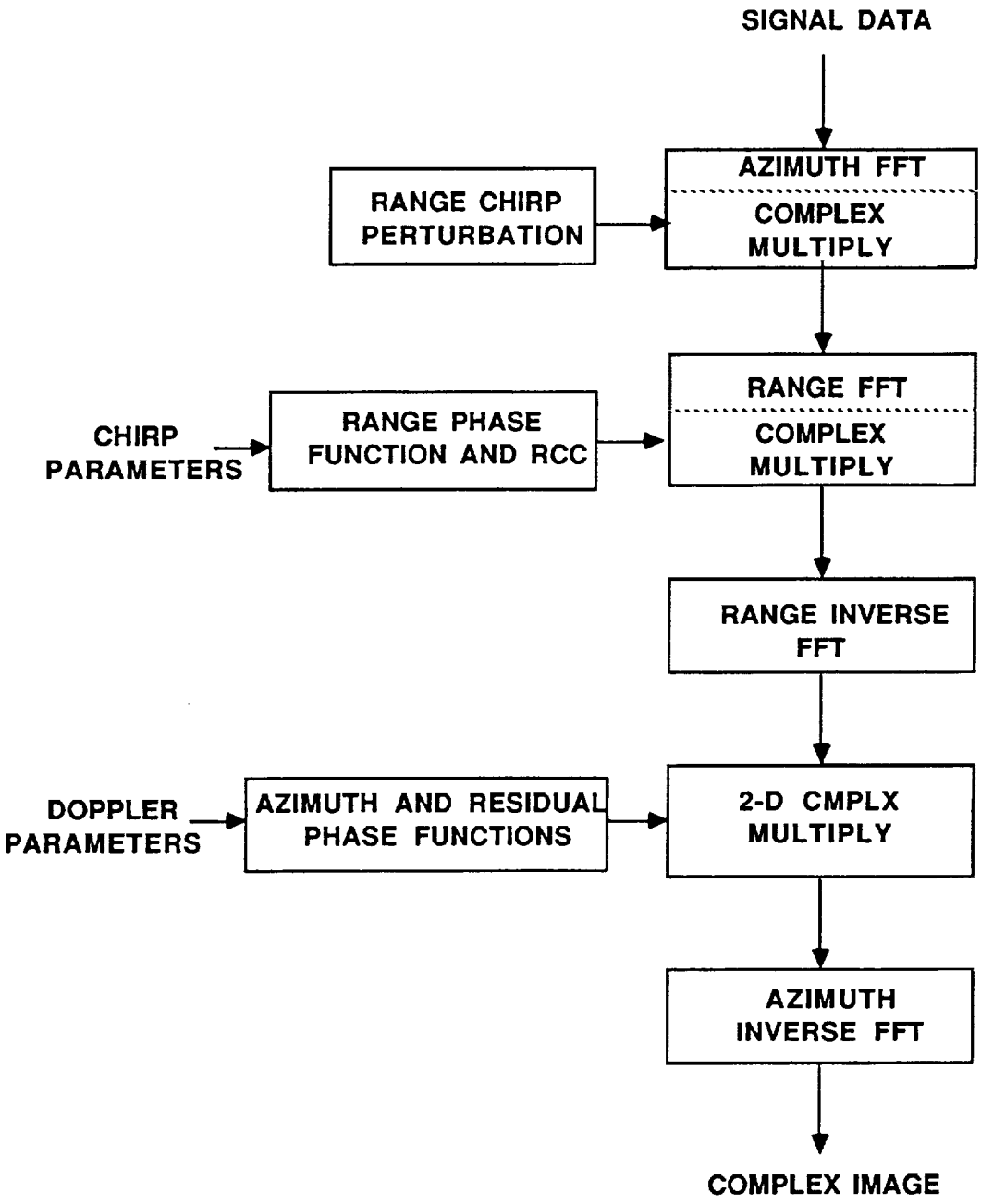
- RESIDUAL PHASE ERRORS FOR THE SECONDARY RANGE COMPRESSION (SRC) AND THE SQUINT IMAGING MODE (SIM) ALGORITHMS (CHANG, ET AL, 1992)

2-D TRANSFORM (WAVE EQUATION) ALGORITHM FLOWCHART



ROCCA, 1987; CAFFORIO, 1991

2-D TRANSFORM (CHIRP SCALING) ALGORITHM FLOWCHART



RANEY, 1991

SAR CORRELATOR: TRENDS AND TECHNOLOGIES

ARCHITECTURE OVERVIEW

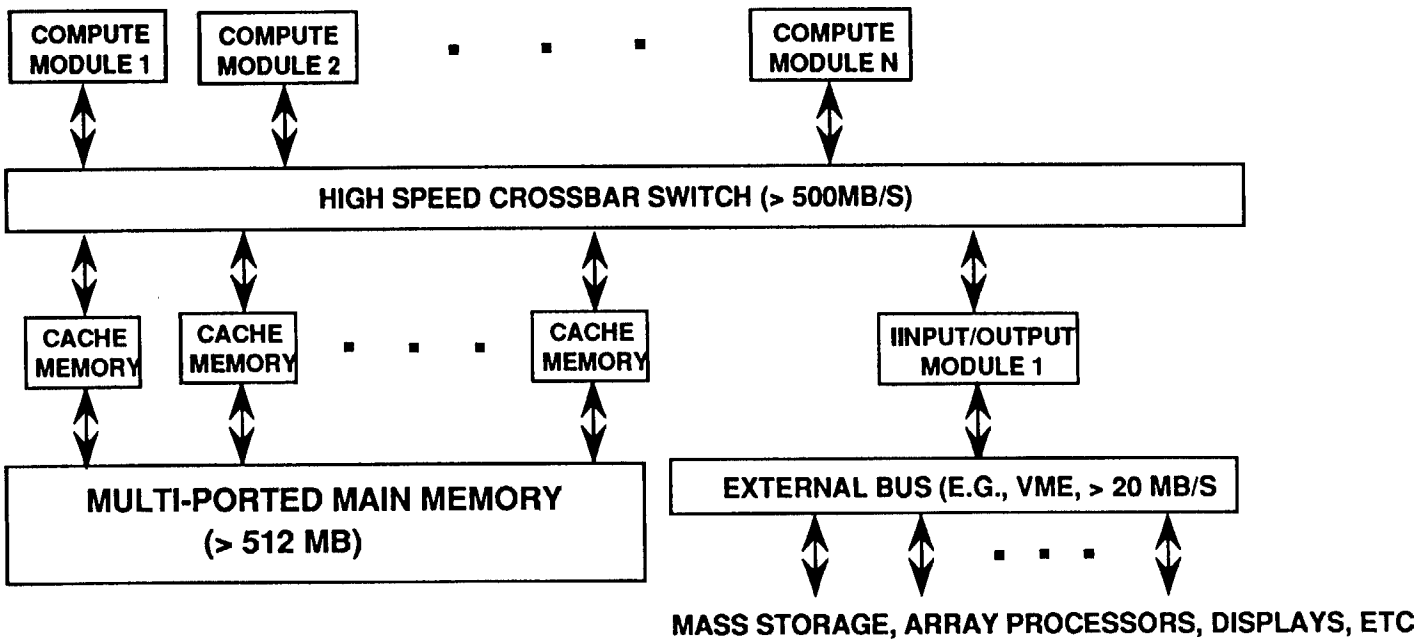
- COMMON NODE
  - USED IN MOST OPERATIONAL SAR PROCESSORS, SHARED MAIN MEMORY, LOW COST, PORTABLE S/W, CONSTRAINED BY NODE (BUS, SWITCH) BANDWIDTH
  - GENERAL PURPOSE COMPUTERS (WITH ACCELERATORS): WORKSTATIONS
  - CUSTOM ARCHITECTURES: COMMON SIGNAL PROCESSOR

- PIPELINE
  - LIMITED APPLICATION PROCESSOR (ONE PRODUCT), BEST ARCHITECTURE FOR REAL-TIME PROCESSING, NOT EASILY ADAPTABLE TO NEW PRODUCTS OR SENSORS, SINGLE FAILURE SHUTDOWN
  - ADVANCED DIGITAL SAR PROCESSOR (ADSP): JPL BUILT FOR SEASAT, MGN
  - AIRBORNE SAR PROCESSORS: QUICK-LOOK ON-BOARD, KRAS, LORAL

- MASSIVELY PARALLEL
  - UNLIMITED COMPUTATIONAL CAPACITY, GRACEFUL DEGRADATION, LOW COST PER PROCESSOR, DIFFICULT I/O, COMPLEX SOFTWARE DEVELOPMENT, FUTURE FOR ALL LARGE COMPUTATION TASKS
  - MIMD (DUAL PARALLELISM): THINKING MACHINES CM-5, INTEL I-WARP
  - SIMD MACHINES: DEC MASSPAR

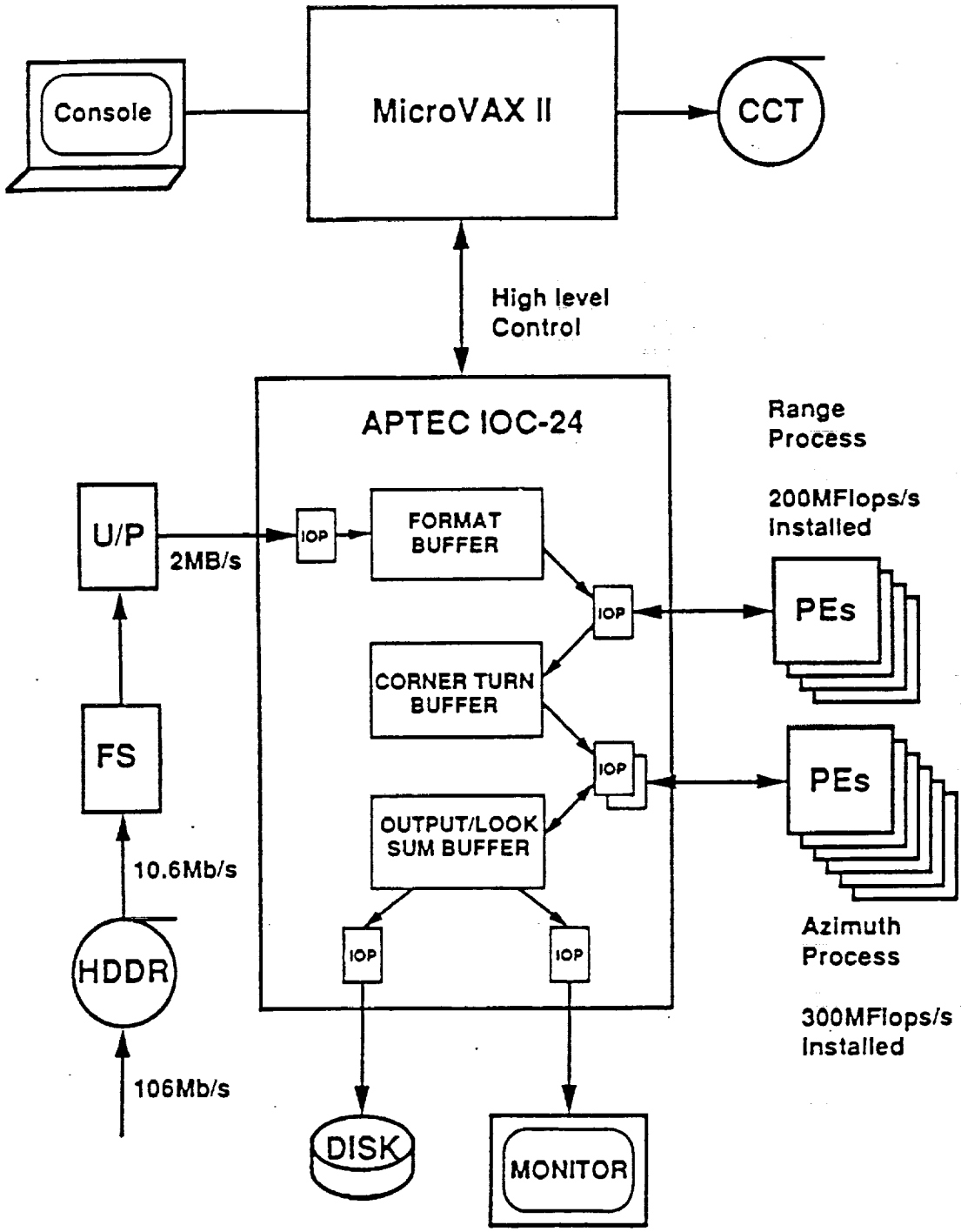
SAR CORRELATOR ARCHITECTURES

I) GENERAL PURPOSE COMPUTERS WITH (OR WITHOUT) SPECIAL PROCESSORS



- ADVANTAGES
  - HIGH LEVEL OPERATING SYSTEM (SIMPLE TO PROGRAM), SOFTWARE STANDARDS/PORTABILITY
- DISADVANTAGES
  - HIGH COST PER MFLOP, PERFORMANCE LIMITED BY CENTRAL BUS DATA RATE

ADVANCED SAR CORRELATOR ARCHITECTURE
BRITISH AEROSPACE ERS-1 PROC



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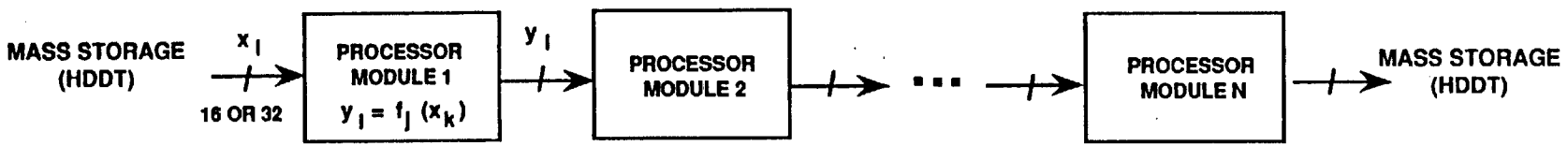
SAR CORRELATOR ARCHITECTURES

II) CUSTOM PIPELINE PROCESSORS



- ADVANTAGES
  - OPTIMUM ARCHITECTURE FOR SAR IN TERMS OF THROUGHPUT, LOW COST/MFLOP
- DISADVANTAGES
  - INFLEXIBLE ARCHITECTURE, NO GRACEFUL DEGRADATION, TYPICALLY REQUIRES ALGORITHM APPROXIMATIONS

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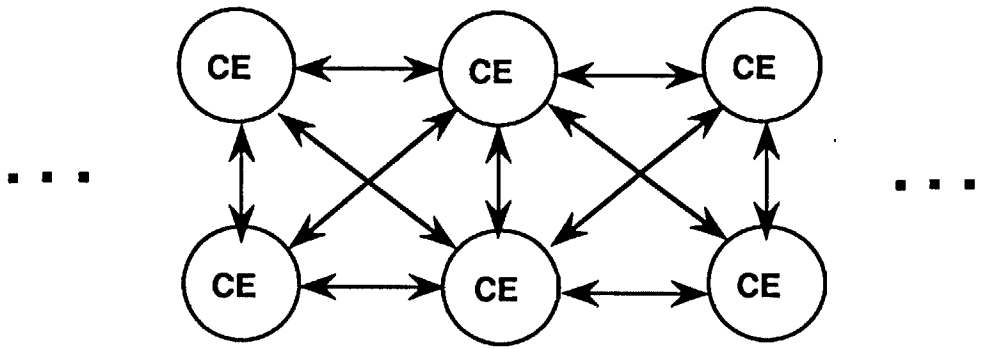
SAR CORRELATOR ARCHITECTURES

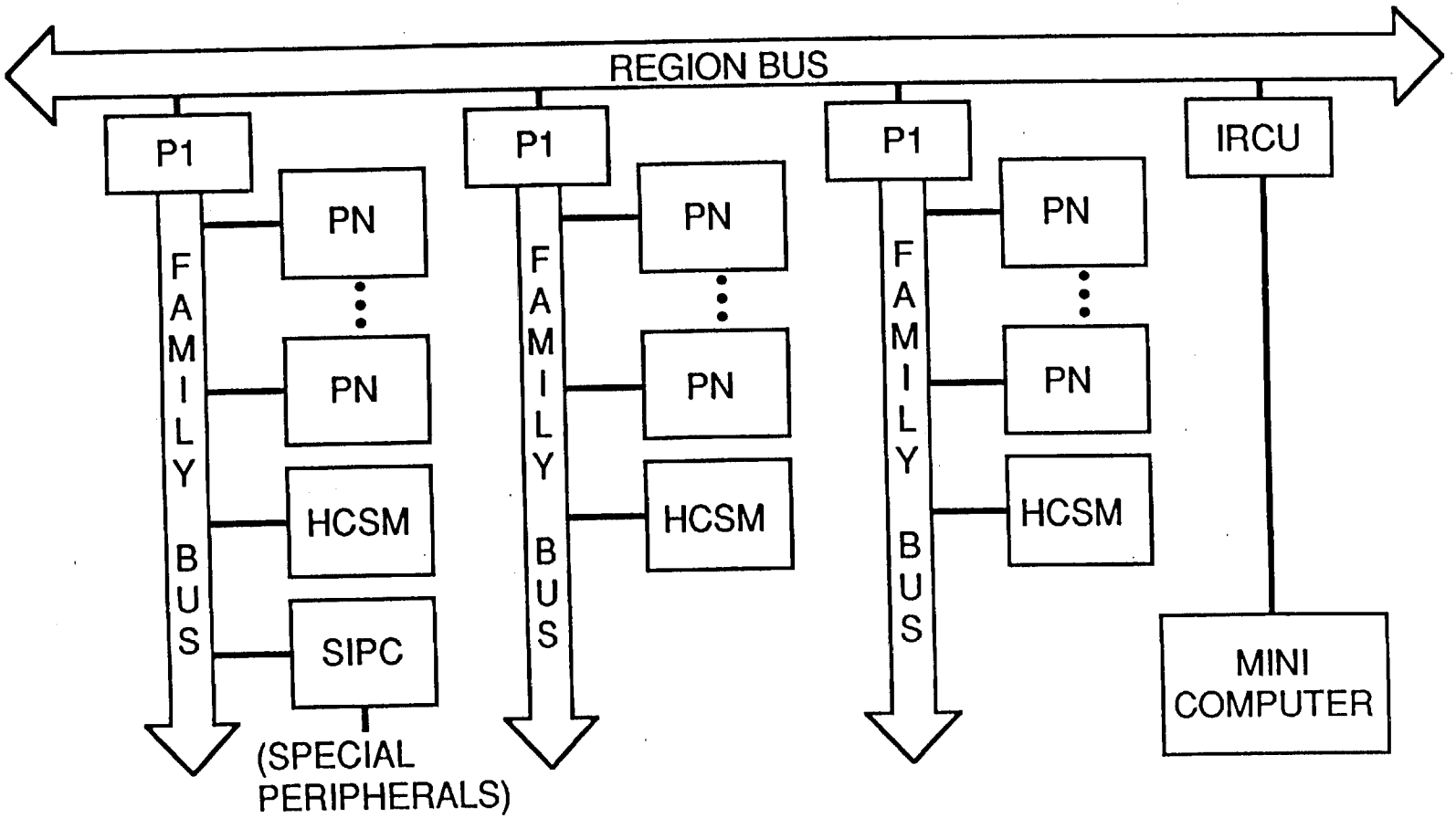
III) MASSIVELY PARALLEL PROCESSORS



- ADVANTAGES - LOW COST/MFLOP, UNLIMITED SYSTEM EXPANDABILITY, HIGH RELIABILITY
- DISADVANTAGES - PRIMITIVE OPERATING SYSTEMS, REQUIRES SPECIAL ALGORITHMS FOR EFFICIENCY, POOR I/O TO EACH PROCESSOR

SAR CORRELATOR DESIGN

EMMA MIMD CONCURRENT ARCHITECTURE



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OPERATIONAL SAR PROCESSING SYSTEMS

ARCHITECTURES

- COMMON NODE
  - ERS-1 FAST DELIVERY PROCESSORS, AUSTRALIA PAF, CANADA PAF, GERMANY PAF AND X-SAR
- PIPELINE
  - ERS-1/JERS-1 ALASKA SAR FACILITY, MAGELLAN
- MASSIVELY PARALLEL
  - ITALY PAF, NASA/JPL SIR-C

ALGORITHMS

- SPECAN
  - NASA/JPL MAGELLAN, RADARSAT SCANSAR, NASA/JPL SIR-C SURVEY PROCESSOR
- RANGE/DOPPLER
  - ERS-1 PAF AND FAST DELIVERY PROCESSORS
  - NASA/JPL SEASAT, SIR-B AND SIR-C PRECISION PROC
  - DLR XSAR, ASF ERS-1 AND JERS-1, NASDA JERS-1
- 2-D TRANSFORM
  - RESEARCH PROCESSORS: ESA, CCRS, JPL, DLR

SAR CORRELATOR: TRENDS AND TECHNOLOGY

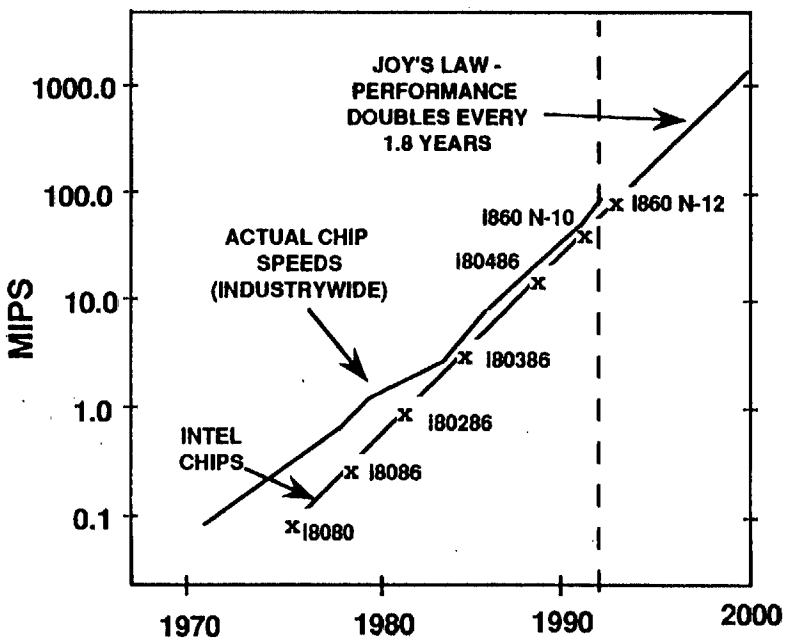
PROJECTED HARDWARE NEEDS/PERFORMANCE

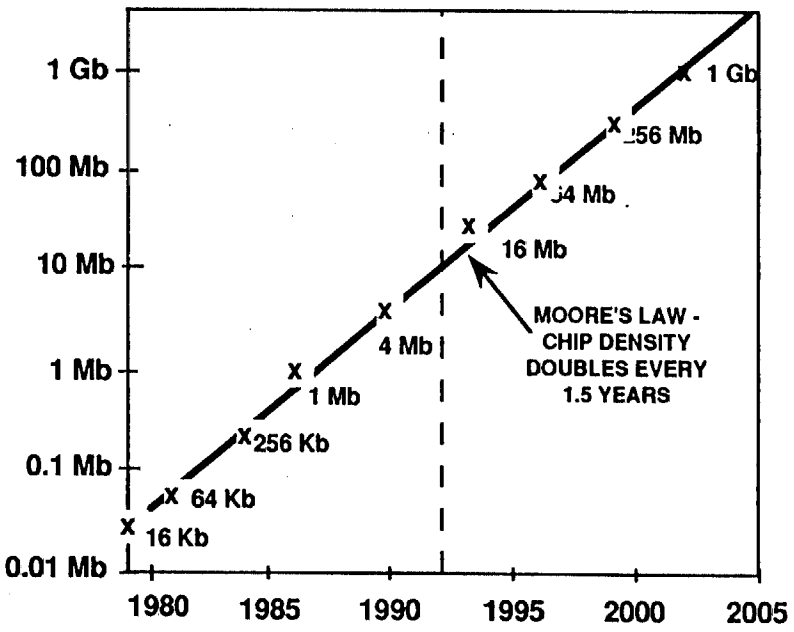
JPL PROCESSOR HARDWARE REQUIREMENTS*

	INPUT DATA RATE (MBps)	DATA VOLUMES (Gsamples/DAY)	COMPUTATIONAL CAPACITY (GFLOPS)	MAIN MEMORY (MB)
AIRSAR	0.5	5	0.2	400
SIR-C	0.8	10	0.3	500
RADARSAT	1.2	57	0.8	750
EOS SAR	6.0	173	3.3	900

* ASSUME 10 SHIFT PER WEEK OPERATIONS WITH 50% REPROCESSING

MICROPROCESSOR PERFORMANCE AND MEMORY CHIP CAPACITY EVOLUTION





SAR CORRELATOR: TRENDS AND TECHNOLOGIES
SUMMARY

- CURRENT OPERATIONAL SYSTEMS (PAST 5 YEARS TO PRESENT)
  - ALGORITHMS: RANGE/DOPPLER
  - ARCHITECTURES: COMMON NODE

- FUTURE OPERATIONAL SYSTEMS (PRESENT TO NEXT 5 YEARS)
  - ALGORITHMS: 2D TRANSFORM
  - ARCHITECTURES: MASSIVELY PARALLEL

- DATA SYSTEM SUCCESSES (PAST 5 YEARS)
  - RADIOMETRIC/POLARIMETRIC CALIBRATION
  - DATA FORMATS (CEOS)
  - RELIABLE CORRELATOR DESIGNS

- DATA SYSTEM CHALLENGES (NEXT 5 YEARS)
  - END-TO-END OPERATIONS, INCLUDING DATA DISTRIBUTION
  - GEOPHYSICAL PROCESSORS, OPERATIONAL REDUCTION OF DATA TO HIGH LEVEL PRODUCTS
  - USER INTERACTION IN MISSION OPERATIONS, TELESCIENCE