P.21

MASSIVELY PARALLEL PROCESSOR

The Massively Parallel Processor (MPP) was delivered to NASA Goddard in May 1983, by Goodyear Aerospace Corporation following four years of development. MPP is the product of a research and technology program designed to evaluate the application of a computer architecture containing thousands of processing elements (PE's), all operating concurrently, to the computational requirements of the sensors of the next decade.

Major applications of the MPP are in the area of image processing (where operands are often small integers) from very high spatial resolution passive image sensors, signal processing of RADAR data, and numerical modeling simulations of climate.

At the heart of the MPP is a custom integrated circuit chip containing 8 PE's. 2112 of these chips have been combined with commercial memory and control chips to pack into 18 square feet of floor space the capability to perform 400 million floating point operations per second and 6 billion fixed point operations per second. The system can be programmed in assembly language or a high level language, Parallel Pascal, which is an extension of standard Pascal. Research is underway to develop techniques and programming tools to better expose the power of the massive parallelism.

Because the MPP is a one-of-a-kind system and is not a commercial product supported by the field engineering wing of the manufacturer's organization, NASA has assumed responsibility for providing all spare printed circuit boards, spare component parts, diagnostic software, and an on-site maintenance engineer. Spares exist for only 11% of the printed circuit board assemblies so hardware failures must often be traced to the failed component while users wait. This situation has proved workable, though ocassionally tenuous when several failures occur close together in time.

The MPP is being developed as a national resource around which will grow a diverse community of science and applications users requiring its unique parallel processing capabilities. Their work will help determine the practical computational limits of the MPP's parallel architecture. A Space Science and Applications Notice (AN) titled "Computational Investigations Utilizing the Massively Parallel Processor" was issued in December 1984. It announced an ongoing opportunity to carry out computational investigations exploiting the unique characteristics of the MPP. Despite the fact that no funding was offered, forty proposals were received. Their topics were spread almost evenly across the categories of signal and image processing, earth sciences, physics, and computer science. Those investigators whose proposals are accepted will form the first MPP working group. Their experiences and recommendations will play a large factor in motivating future enhancements to the current system and in justifying future NASA efforts in parallel processor development.

THE MASSIVELY PARALLEL PROCESSOR (MPP)

506-58-16 DATA SYSTEMS

506-54-56 COMPUTER SCIENCE

COMPUTER SCIENCE / DATA SYSTEMS

TECHNICAL SYMPOSIUM

LEESBURG, VA

APRIL 17, 1985

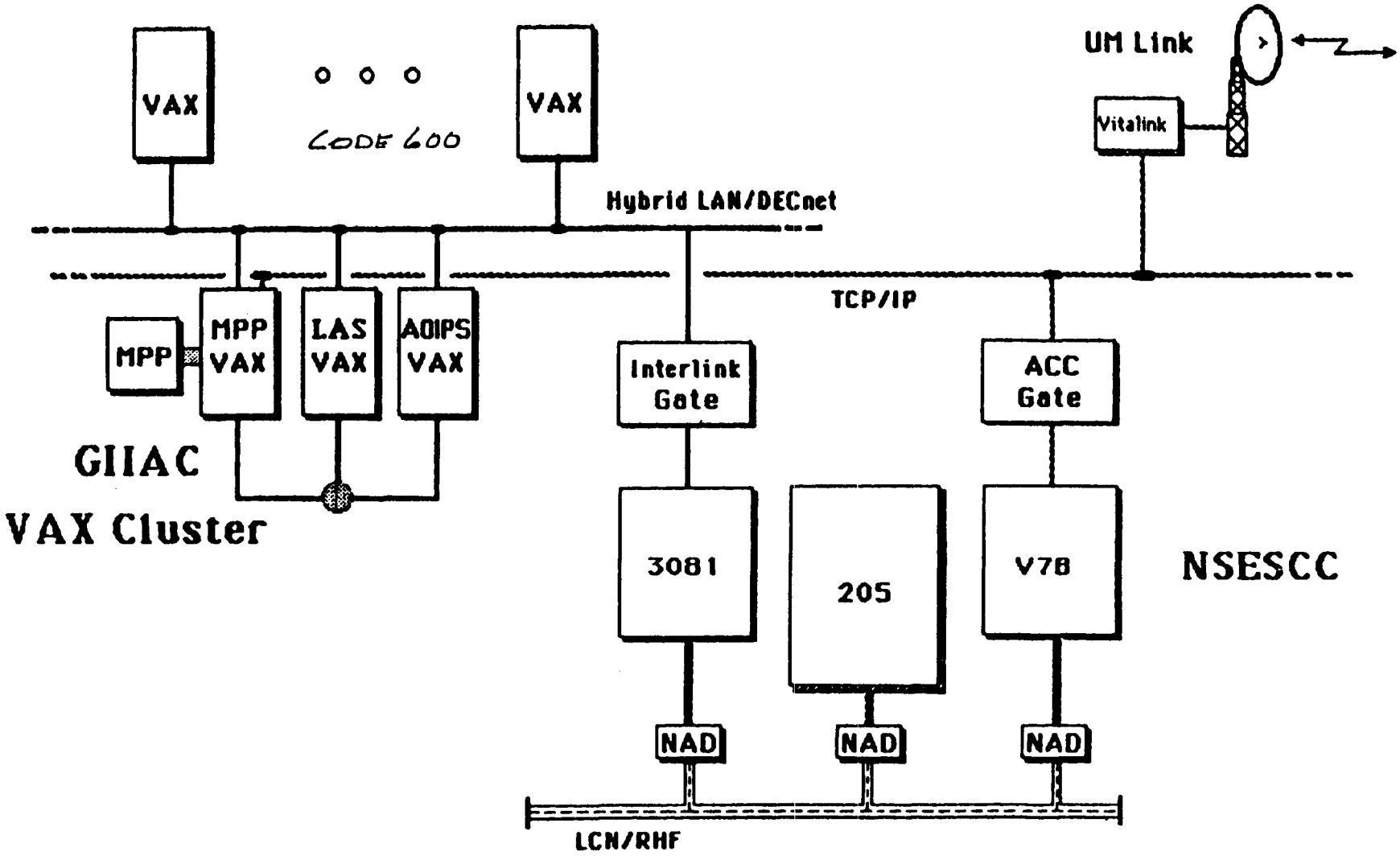
JIM FISCHER NASA/GSFC CODE 635

OVERVIEW

- BACKGROUND AND STATUS
- ARCHITECTURE AND PROGRAMMING
- HARDWARE RELIABILITY
- APPLICATIONS - TODAY
- DEVELOPMENT AS A NATIONAL RESOURCE FOR PARALLEL ALGORITHM RESEARCH

BACKGROUND

- THE MPP IS A 2-DIMENSIONAL ARRAY CONSISTING OF 16,384 (128 X 128) SIMPLE PROCESSORS.
- THE MPP IS THE RESULT OF A NASA R & D PROGRAM TO DEVELOP A HIGH SPEED IMAGE PROCESSING COMPUTER.
- THE INITIAL CONCEPT AND DESIGN OF THE MPP WAS DEVELOPED AT THE GODDARD SPACE FLIGHT CENTER.
- GOODYEAR AEROSPACE CORPORATION DEVELOPED THE MPP SYSTEM UNDER CONTRACT.



FUTURE NETWORK

Access to Supercomputers
via Hybrid LAN

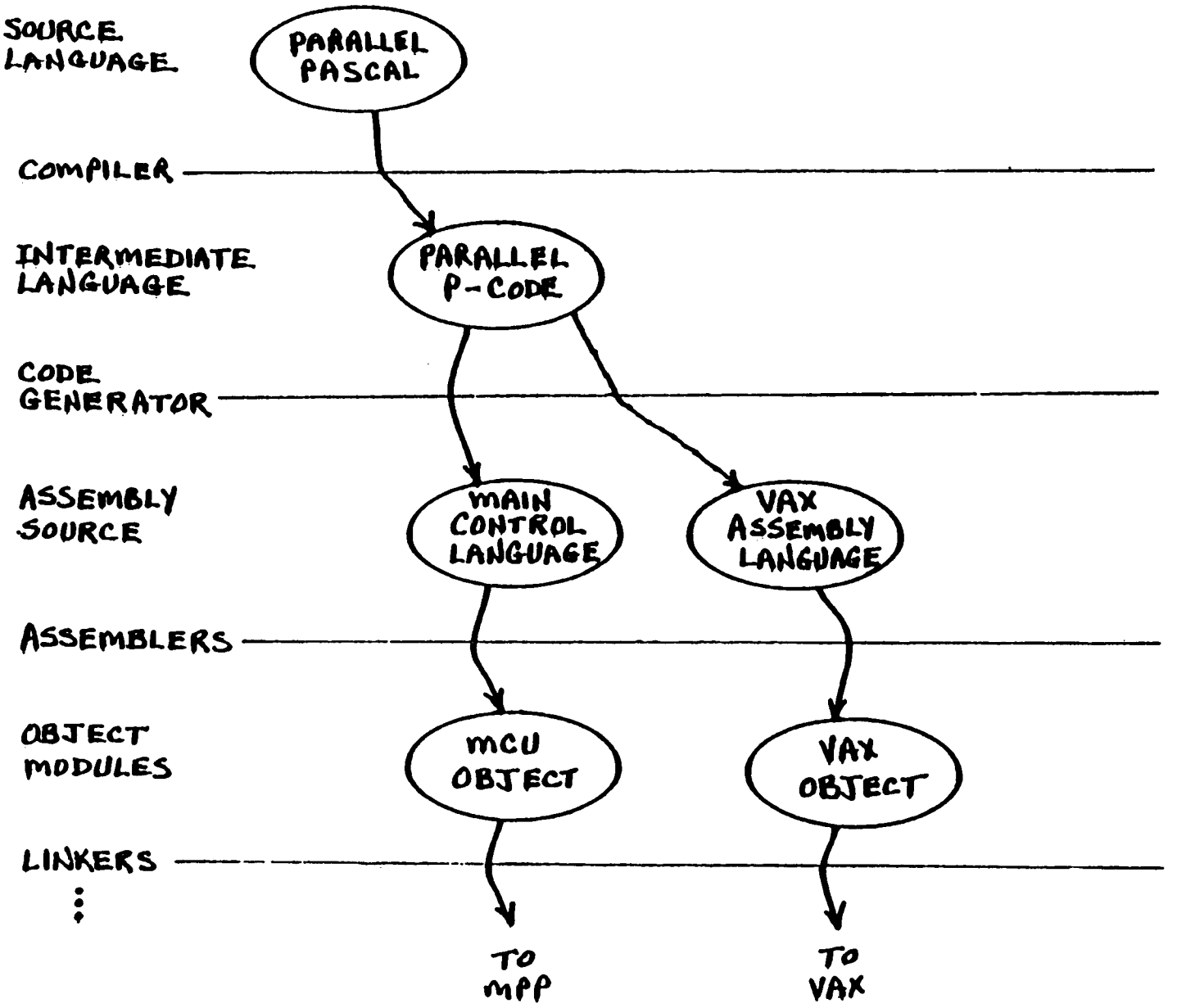
PROGRAMMING THE MPP

FOR TIGHT CONTROL OF HARDWARE	-	USE ASSEMBLY LANGUAGE
FOR PROGRAM DEVELOPMENT	-	USE HIGH LEVEL LANGUAGE PARALLEL PASCAL
FOR TRANSPARENT USE	-	USE PRE-PACKAGED ROUTINES REQUEST VIA MENUS
FOR BEST ALGORITHM MAPPING TO HARDWARE	-	(ACTIVE AREA OF RESEARCH)

PARALLEL PASCAL (AN EXTENSION OF STANDARD PASCAL)

```
VAR
  A    : PARALLEL ARRAY [ 0..127, 0..127 ] OF 0..511;
  B, C : PARALLEL ARRAY [ 0..127, 0..127 ] OF 0..255;
  M    : PARALLEL ARRAY [ 0..127, 0..127 ] OF BOOLEAN;

BEGIN
  WHERE M = 1 DO
    A := B + C;          { UP TO 16384 ARRAY ELEMENTS
                           PROCESSED SIMULTANEOUSLY }
END.
```


SOURCE LANGUAGE
PARALLEL PASCAL
COMPILER
INTERMEDIATE LANGUAGE
PARALLEL P-CODE
CODE GENERATOR
ASSEMBLY SOURCE
MAIN CONTROL LANGUAGE
VAX ASSEMBLY LANGUAGE
ASSEMBLERS
OBJECT MODULES
MCU OBJECT
VAX OBJECT
LINKERS
TO MPP
TO VAX

MPP HARDWARE RELIABILITY SINCE NOVEMBER 15, 1984

	UP AVAILABLE	*DEGRADED BUT AVAILABLE	DOWN
NOVEMBER (16 DAYS)	79	-	21
DECEMBER	82	-	18
JANUARY	60	34	6
FEBRUARY	55	15	30
MARCH	96	-	4

ALL NUMBERS REFLECT PERCENTAGE OF NORMALLY SCHEDULED HOURS OF OPERATION:

(3 SHIFTS/DAY 6 DAYS/WEEK)

* THE GODDARD INVENTORY OF A CRITICAL COMMERCIAL CHIP WHICH FAILED OFTEN, HAD NOT BEEN MANUFACTURED IN FOUR YEARS, AND WAS UNPURCHASABLE, WENT TO ZERO. COMPATIBLE 'REJECT' CHIPS WERE EVENTUALLY LOCATED AND THE PROBLEM WAS RELIEVED.

MPP APPLICATIONS - TODAY

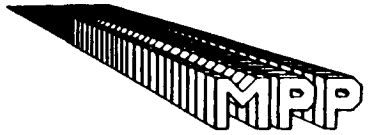
TYPE OF WORK	INSTITUTION	STATUS
ISODATA CLUSTERING ALG	GSFC/630	WORKING
SINGLE LAYER FLUID MODEL	GSFC/630/611	WORKING
MAXIMUM LIKELIHOOD CLASSIFIER	GSFC/630/USDA	WORKING
LARGE IMAGE ROTATION & WARPING	GSFC/680/PENN ST	WORKING
CONTEXTUAL CLASSIFIER	GSFC/630	WORKING
CONNECTED COMPONENTS LABELING	GSFC/630	WORKING
TEXTURAL FEATURE EXTRACTION	GSFC/630	WORKING
SIR-B SAR SIGNAL PROCESSING	GSFC/630	ADV DEBUG
NUMBER FACTORING	DOD/GOODYEAR	ADV DEBUG
COMPUTATIONAL ENGINE RESEARCH	GSFC/630	ADV DEBUG

MPP APPLICATIONS - TODAY (CONTINUED)

TYPE OF WORK	INSTITUTION	STATUS
ASSOCIATIVE QUERY PROCESSING	GSFC/52Ø	DEBUG
CONVOLUTION (IMAGE FILTERING)	GSFC/CORNELL	DEBUG
MEDIAN FILTERING OF IMAGES	GSFC/CORNELL	DEBUG
TOPOGRAPHIC DATA FROM SIR-B STEREO PAIRS	GSFC/63Ø	DEBUG
TWO LAYER FLUID MODEL	GSFC/611	DEBUG
CLASSY CLUSTERING ALG	GSFC/63Ø	DEBUG
THEMATIC MAPPER GEOMETRIC CORRECTION	GSFC/GOODYEAR	DEBUG
IMAGE DEBLURRING	GSFC/681	DESIGN
HILLSLOPE HYDROLOGICAL MODEL	GSFC/62Ø	DESIGN

TIMING SUMMARY

	VAX	VAX WITH AP180V ARRAY PROCESSOR	MPP
ISODATA CLUSTERING		3 HRS	20 SEC
MAXIMUM LIKELIHOOD CLASSIFICATION	15 MIN		0.5 SEC
'CLASSY' CLUSTERING (128 X 128 ESTIMATE)		2 - 3 HRS	60 SEC
CONTEXTUAL CLASSIFIER		2 - 3 HRS	18 SEC
SYNTHETIC APERTURE RADAR 'SEASAT' IMAGE GENERATION		2 - 3 HRS	3 - 5 MIN

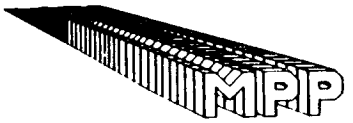


A NATIONAL RESOURCE

MPP GOAL

ADVANCE STATE-OF-THE-ART IN CONCURRENT PROCESSING FOR

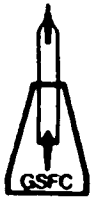
- IMAGE ANALYSIS & INFORMATION EXTRACTION
- SIGNAL PROCESSING & KALMAN FILTERING
- ATMOSPHERIC & OCEANOGRAPHIC MODELING
- BASIC PHYSICAL, MATHEMATICAL, & COMPUTER SCIENCES RESEARCH



A NATIONAL RESOURCE

MISSION OBJECTIVES FOR THE MPP

- —DEMONSTRATE THE MPP'S UNIQUE SCIENTIFIC APPLICATIONS CAPABILITIES
- —FACILITATE RESEARCH PROJECTS THAT ARE REASONABLE ONLY BY USING MPP
- —EVALUATE THE MPP SYSTEM HARDWARE & SOFTWARE FOR GENERAL USER AVAILABILITY
- —RECOMMEND FUTURE ENHANCEMENTS (SOFTWARE & HARDWARE) NEEDED FOR GENERAL SCIENTIFIC USE



BACKGROUND OF THE APPLICATIONS NOTICE

- ANNOUNCED AN ONGOING OPPORTUNITY TO CARRY OUT COMPUTATIONAL INVESTIGATONS EXPLOITING THE UNIQUE CHARACTERISTICS OF THE MPP
- SIGNED DECEMBER 20, 1984, BY DR. EDELSON
- MORE THAN 2000 DISTRIBUTED NATIONALLY

OVERVIEW OF PROPOSALS RECEIVED

- 40 PROPOSALS RECEIVED
- PRINCIPLE CATEGORIES:
  - 7 - SIGNAL/IMAGE PROCESSING
  - 8 - EARTH SCIENCES
  - 10 - PHYSICS
  - 15 - COMPUTER SCIENCE

SIGNAL/IMAGE PROCESSING

SYNTHETIC APERTURE RADAR PROCESSING IMPROVEMENTS	MANGO NRL
RECONSTRUCTION OF CODED-APERTURE X-RAY IMAGES	YIN GSFC/682
COMET HALLEY LARGE-SCALE IMAGE ANALYSIS	KLINGLESMITH GSFC/684
AUTO DETECT AND CLASSIFY GALAXIES ON DEEP-SKY PICTURES	HEAP GSFC/681
FIXED POINT OPTIMAL NONLINEAR PHASE DEMODULATION	BUCY USC
USE SPATIAL INFO FOR ACCURATE INFORMATION EXTRACTION	TILTON GSFC/636

EARTH SCIENCES

KALMAN FILTERING AND BOOLEAN DELAY EQUATIONS	GHIL UCLA
COMPARE W/OTHER SUPERCOMPUTERS FOR LANDSAT DATA PROC	OZGA USDA
TROPOSPHERIC TRACE GAS MODELING	CARMICHAEL IOWA
NUMERICAL MODELING WIND-DRIVEN INDIAN OCEAN CIRC.	O'BRIEN FLORIDA STATE
MAGNETOSPHERIC INTERACTIVE MODEL USING CURRENT SHEETS	WHIPPLE UCSD
AUTO TECHNIQUES TO DETECT GEOLOGICAL FRACTURE PATTERNS	RAMAPRIYAN GSFC/636
NEAR-REAL-TIME PROCESSING OF GLOBAL POSITIONING SATELLITE DATA FOR PRECISION ORBIT DETERMINATION	MADRID JPL

PHYSICS

PARTICLE SIMULATION OF PLASMAS	STOREY STANFORD
PROBLEMS IN CONDENSED MATTER PHYSICS AND CHEMISTRY	SULLIVAN NBS
SIMULATIONS OF BEAM PLASMA INTERACTIONS	LIN SW RESEARCH INST
DYNAMICS OF COLLISIONLESS STELLAR SYSTEMS	WHITE SPACE TELESCOPE INST
WAVE SCATTERING BY ARBITRARILY SHAPED TARGETS	TOBOCMAN CASE WESTERN RES U
ADAPTING A NAVIER-STOKES CODE	GROSCH ICASE
FREE-ELECTRON LASER DESIGN STUDIES	VON LAVEN KMS FUSION
NUMERICAL CALCULATIONS OF CHARGED PARTICLE TRANSPORT	EARL MARYLAND

COMPUTER SCIENCE

GRAPHICS APPLICATIONS	DAVIS NCSU
SOLUTION OF COMPLEX, LINEAR SYSTEMS OF EQUATIONS	IDA U AKRON
SIMULATE APPLICATIVE PROGRAMMING STORAGE ARCHITECTURE	O'DONNELL INDIANA
SORTING AND SIGNAL PROCESSING ALGORITHMS	DEMUTH U TULSA
STOCHASTIC AND REACTION-DIFFUSION CELLULAR AUTOMATA	HASTINGS HOFSTRA
FORTH, AN INTERACTIVE LANGUAGE FOR CONTROLLING THE MPP	KLINGLESMITH GSFC/684
DIAGRAMMATIC INFORMATION PROCESSING IN NEURAL ARRAYS	BARDEN INDIANA
SPACE PLASMA GRAPHICS ANIMATION	GREENSTADT TRW
GENERATE TOPOGRAPHIC MAPS FROM SPACECRAFT IMAGERY	STRONG GSFC/636
ANIMATED MODELS OF SPACE & EARTH SCIENCES DATA	TREINISH GSFC/634

IMPACTS OF THE MPP ON PROBLEM SOLVING

- DRAMATICALLY IMPROVE MACHINE RESPONSE TIME
- MAKE MANY MORE COMPUTATIONALLY INTENSIVE PROBLEMS REASONABLE TO PERFORM
- REDUCE FUTURE SYSTEM SIZE AND COST