Status Report on the Study of

TECHNOLOGY APPLICATIONS FOR TACTICAL DATA SYSTEMS

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by

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TECHNOLOGY APPLICATIONS FOR TACTICAL DATA SYSTEMS

I. PURPOSE AND SCOPE

The purpose of this study is to investigate and evaluate new hardware technologies for use in tactical data systems in the 1970-80 period. The study is intended to supply Navy systems planners with sufficient information about the capabilities and feasibilities of alternative hardware technologies to permit them to make informed decisions in selecting hardware approaches and devices for implementing specific functions to optimize the design of future systems.

This study has been conducted in close coordination with Informatics' MTACCS and Phase II ANTACCS studies. Requirements generated by Informatics for specific types of hardware functions are a major criteria used in selecting technologies for investigation in this study. The results of investigations and evaluations of specific hardware technologies are being supplied to Informatics on a continuing basis to aid in their development of systems concepts.

This study is divided into two major areas. One deals with the investigation and evaluation of hardware technologies for 1970 era tactical data systems and the other deals with the effect of these new technologies on the maintainability of future systems. The hardware technologies covered fall into four major areas - components and packaging techniques, memories, displays, and input/output equipment. The maintainability phase is concerned with the impact that new technologies will have on the maintainability of tactical data equipment and the changes in maintenance concepts necessary to properly utilize new technologies to improve maintainability.

The material in this presentation is covered in greater detail in the Mid-Project Report on this study submitted recently to Mr. R. G. . Tuttle in the Advanced Warfare Systems Division (Code 493) of ONR.

II. HARDWARE TECHNOLOGY

The progress in electronic and magnetic batch-fabrication technologies, which has been much more rapid than had been anticipated by most of the industry, promises significant improvements in size, weight, power, cost, and failure rates. The term "batch-fabrication" refers to processes that provide the ability to fabricate simultaneously, in a single set of processing operations, large numbers of circuit elements and the interconnections necessary to connect them into circuits. Batch-fabrication techniques permit not only the fabrication and interconnection of the elements of an individual circuit, but also of large arrays of circuits with the appropriate interconnections between circuits to form a major function or group of functions.

The characteristics anticipated for major types of integrated circuits and storage devices are summarized in Tables 1 and 2. Failure rates for digital circuits in the order of .0005% to .0001% per thousand hours are anticipated for the early 1970's. Typical costs for the technologies summarized in Tables 1 and 2 are:

Type	Cost
Monolithic Integrated Circuit Logic	3 to 5¢ per circuit (in large arrays)
MOS Integrated Circuit Logic	2 to 4¢ per circuit (in large arrays)
Registers and High-Speed Control Memories	2 to 5¢ per bit
Main Internal Memories	1 to 3¢ per bit
Solid-State Random Access On-Line Auxiliary Storage	0.2 to 1¢ per bit

Technology	Performance Anticipated by 1970	Comments
Hybrid discrete/ thin-film circuits	1 to 10 ns propagation delay 5 to 20 mc clock rate	Useful where high ratio of passive to active components is required (e. g. linear circuits) and where higher power capability is required. Higher cost and probably lower reliability.
Monolithic circuits	0.5 to 10 ns propagation delay 10 to 50 mc clock rate	Low cost, high speed, and high reliability. High value and high tolerance passive components are very difficult, but the use of extra active elements can help compensate for this.
Hybrid monolithic/ thin-film circuits	1 to 10 ns propagation delay 5 to 20 mc clock rate	Compromise between the advantages and disadvantages of discrete components and monolithic circuits. More expensive than monolithic circuits but useful for linear circuits requiring higher tolerance passive components.
Metal-oxide-semiconductor (MOS) circuits	20 to 100 ns propagation delay 2 to 10 mc clock rate	Simpler to make and easier to fabricate large arrays of interconnected circuits. Lower power consumption. Speed approximately one order of magnitude slower than monolithic circuits.
Silicon-on-sapphire circuits	20 to 100 ns propagation delay 2 to 10 mc clock rate	Fabrication suitable for large arrays. Promising, but presently being pushed by only one company.
Active thin-film circuits	Too early to predict	Potentially cheaper and easier to fabricate very large arrays. Feasibility is not proven and utilization much farther away.

MAJOR TYPES OF INTEGRATED CIRCUITS

Table 1

Type of Storage	Registers & High Speed Control Memories: Typical Capacity (Words)	Registers & High Speed Control Memories: R/W Cycle Time	Main High-Speed Internal Memories: Typical Capacity (Words)	Main High-Speed Internal Memories: R/W Cycle Time	Solid-State On-Line Auxiliary Storage Devices: Typical Capacity (Words)	Solid-State On-Line Auxiliary Storage Devices: R/W Cycle Time	Comments
Integrated Ckt. Arrays	256	50 ns 0	0.01x10^6	0.2 us			Most promising for very high speed registers and control memories.
MOS Arrays	512	250 ns	0.02x10^6	0.7 us			Promising for low cost intermediate capacities; Volatility is disadvantage.
Planar Thin-Film	512	100 ns	0.1x10^6	0.5 us	2x10^6	1 us	Promising for fast control memories, possibly for on-line aux storage; Questionable for main internal mem.
Laminated Ferrite	512	150 ns	0.1x10^6	2 us			Reasonable yields not proven for capacities over a few hundred words; Actively pushed by only one company.
Plated wire	512	250 ns	0.2x10^6	0.5 us	4x10^6	1 us	Very promising in all categories.
Magnetic Core Matrix	512	350 ns	0.1x10^6	0.7 us	2x10^6	3 us	Well established and will be dominant for several years; Will be replaced eventually by batch-fab techniques.
Permalloy-Sheet Toroid			0.2x10^6	20 us	4x10^6	100 us	Potential for very low cost but feasibility and yield are unproven; Actively pushed by only one company.
Continuous-Sheet Cryogenic			2.0x10^6	2 us	20x10^6	5 us	Feasibility still unproven; Not economic for capacities below appx. 10^8 bits because of refrigerant cost.
Ferro-Acoustic					20x10^6	(serial)	In early research stages; Concept promising for low cost block-oriented aux storage, but feasibility not proven.

STORAGE DEVICE CHARACTERISTICS ANTICIPATED IN 1970

Table 2

Achieving the logic circuit costs shown above is dependent upon the use of large arrays of circuits which permit most of the interconnections to be made by batch-fabrication techniques and which permit amortizing packaging and external interconnection costs over a large number of circuits in the package.

Large functional packages will be achieved by a combination of two approaches. Large arrays will be fabricated and interconnected on multi-circuit silicon chips and a number of these chips will be mounted and interconnected by means of batch-fabricated interconnect patterns on a larger substrate to provide large functional packages. These multi-circuit chips and multi-chip packages necessitate functional replaceable or throw-away units that are very large from the standpoint of complexity and function. However, they will be small physically, and any increase in unit cost will be much less than the increase in complexity. Additional research in machine organization and logical design techniques is needed to permit organizing the computer along more highly functional lines to properly utilize larger functional packages.

Optimum use of batch fabrication techniques makes it difficult and undesirable to repair the package by replacing components or circuits within the package. Hence, these large functional units must be considered throw-away units. In some cases, they may be replaceable units that are repairable at state-side depots but not in the field. The use of functionally large throw-away units will:

Minimize external interconnections and leads
Lower initial fabrication costs
Improve reliability
Simplify fault isolation and maintenance

Central processors, internal memories, and solid-state auxiliary memories will benefit to the greatest extent from new batch-fabrication technologies. The digital logic, control, and storage functions in displays and input/output equipments will also benefit from batch-fabrication technologies since they utilize similar components and circuits. However, only limited improvements will be achieved in the portions of displays, very large capacity auxiliary storage, and input/output equipments that require high voltage circuits, high-powered circuits, electro-mechanical components, or optical projection devices.

Very large capacity auxiliary storage will continue to require electro-mechanical devices for the foreseeable future. Characteristics of electro-mechanical auxiliary memories anticipated in 1970 are summarized in Table 3. Costs in the order of 0.001 to 0.01¢ per bit are anticipated. Improvements in size, weight, and reliability will be limited for this type of equipment.

There are a number of promising new display technologies including:

Large screen -

- Photochromic/CRT displays
- Thermo-plastic and photo-plastic light valves
- Electroluminescent matrices
- Laser generated displays

Console displays -

- Cathode-ray tubes
- Electroluminescent matrices
- Opto-magnetic matrices
- Laser generated displays
- Injection electroluminescence matrices

Cathode-ray tubes represent a well established technology that is expected to remain dominant for console displays, at least until 1970.

Type of Device	Capacity Per Unit In Char.	Average Access Time	Data Transfer Rate Ch/Sec	On-Line or Off-Line Storage	Comments
Magnetic Drums	$250x10^6$	80 ms	500,000	On-Line	Large physical volume; Well proven by field use for years.
Fixed-Head Disc Files	$100x10^6$	20 ms	800,000	On-Line	Fastest access time but highest cost; Relatively new with little field experience.
Moving-Head Disc Files	$1,000x10^6$	80 ms	800,000	On-Line	Most field experience of on-line devices; Best cost, capacity, and access time compromise.
Removable Disc Files	$50x10^6$	100 ms	500,000	Either	Relatively new but widely accepted; Offers advantage of both on-line and off-line capability.
Magnetic Tape Loop	$20x10^6$	80 ms	200,000	Either	New and relatively unproven in the field; Made by only one company at present.
Magnetic Tape Reel	$50x10^6$	(serial)	400,000	Off-Line	Well established and proven for many years; Lowest cost per character off line; Serial access.
Magnetic Card Files	$1,000x10^6$	200 ms	300,000	Either	Available several years, but not as well established as discs. Lower cost per char. for large capacity.
Optical Discs	$150x10^9$	Seconds	500,000	Either	New and unproven by field use; Offered by only one company; Read-only; Largest capacity and low cost per character; Very slow access.

ELECTROMECHANICAL AUXILIARY MEMORY CHARACTERISTICS ANTICIPATED IN 1970

Table 3

However, they will be replaced by flat-panel displays that are compatible with integrated circuits and other batch-fabrication technologies as soon as these reach an appropriate point in their development cycle. Compatibility with batch-fabricated electronics and magnetics is a major criteria for evaluation and selection of future display technologies. Unfortunately, most of the technologies suitable for implementing large-screen displays are not likely to meet this criteria by 1970.. Several of the major new display technologies are compared in Table 4 on the basis of their compatibility with batch-fabricated electronics and magnetics. Electroluminescent matrices, opto-magnetic matrices, and injection electroluminescence matrices appear promising from this standpoint, although the voltages required by present electroluminescent displays present a problem. One or more of these technologies will be proven feasible for console displays by 1970 and for large-screen displays a short time later.

Input/output equipment will present the major problem in future systems with respect to cost, size, weight, power, reliability, and maintainability. There are three major approaches to improving future systems from the input/output standpoint:

- Improvements in present types of input/output equipment
- Development of new types of input/output equipment
- Development of system organization techniques that minimize the need for conventional input/output equipment

Characteristics anticipated by 1970 for present types of input/output equipment are summarized in Table 5. The only significant improvements in this area are the replacement of punched paper tape equipment by incremental magnetic tape equipment and the wide use of non-impact type printers.

New types of input/output equipment that offer promise include character recognition equipment, non mechanical keyboards, and

	Low Voltage	Low Power	Small Volume	Digital Selection	Reliability & Life	Low Cost	Adaptability to Batch Fabrication	Feasibility
Cathode-Ray Tube	Poor	Poor	Poor	No	Good	Fair	Poor	Readily available
Electro-luminescent	Poor	Fair	Good	Yes	Fair	Good	Good	By 1970 if ever
Opto-Magnetic	Good	Good	Good	Yes	Good	Good	Good	Unknown at this time
Laser-Luminescent	Fair	Fair	Fair	Yes	Unknown	Fair	Poor	Promising
Injection Electro-luminescence Matrix	Excellent	Good	Good	Yes	Unknown	Good	Good	Unknown at this time

ANTICIPATED COMPATIBILITY OF VISUAL TRANSDUCER TECHNOLOGIES

WITH BATCH-FABRICATED COMPUTERS

Table 4

Magnetic tape units	300,000-400,000 char/sec read write rate	2000-3000 char/inch density
Incremental magnetic tape		
Recorders	800-1000 char/sec record rate	800 char/inch density
Readers	500-600 char/sec read rate	556 char/inch density
Punched cards		
Punches	300-500 cards/min punch rate	
Readers	2000-3000 cards/min read rate	
Line printers		
Impact type (multiple copy)	1500-2000 lines/min	64 character types 132 char/line
Non-impact type (single copy)	3000-5000 lines/min	64 character types 132 char/line

INPUT/OUTPUT EQUIPMENT CHARACTERISTICS

ANTICIPATED BY 1970

Table 5

solid-state replacements for some magnetic tape functions. Voice input and output is also promising for the 1975-80 period. However, the greatest hope for systems improvement with respect to input/output lies in development of system organization techniques that minimize the need for conventional types of input/output equipment. An example of this is the wider utilization of on-line data acquisition devices and on-line displays.

III. MAINTAINABILITY

It has become apparent that functionally large throw-away units not only are desirable from the standpoint of batch-fabrication technologies but also provide a key to significant improvements in maintainability. The use of throw-away units that are significantly larger from the standpoint of function and complexity will be permitted by the lower cost per component and the lower failure rate afforded by batch-fabrication technologies. The use of larger throw-away units will improve maintainability by:

- Reducing training and skill levels required by maintenance personnel,
- Reducing the number of maintenance technicians required,
- Reducing supply and logistics requirements,
- Simplifying and speeding fault isolation,
- Minimizing down time

These improvements will both reduce maintenance costs and increase systems availability.

In the early 1970's, a batch-fabricated computer with capability equivalent to that of the present USQ20B will cost in the order of $25,000 compared to approximately $125,000 for the most recent USQ20B procurement.. Such a computer can be packaged in ten or fifteen replaceable units each costing in the order of $1500 to $3000. Anticipated reliability improvements between one and two orders of magnitude will result in mean-time-between-failures in excess of one year for a complete computer. Hence, it will be reasonable to consider each of these ten or fifteen packages as a throw-away unit. This will reduce computer maintenance to merely locating the fault in one of ten or fifteen units, which can be achieved by a relatively simple diagnostic program, and then replacing that unit. Later during the 1970-80 period, the complete computer will become a replaceable unit. This will be particularly feasible if a multi-computer system organization concept based on the use of identical small modular computers is adopted. In this case, the complete small modular computer will become a throw-away unit in the 1975-80 period.

The maintenance concept recommended is based on the use of very large functional throw-away units and on no shipboard repair for electronic portions of the data handling system. Shipboard maintenance will be required for the electro-mechanical equipment that cannot be eliminated from the system. Adopting this approach to maintenance will require significant changes in concepts and attitudes towards maintenance on the part of Navy systems planners, budgeters, and users.

IV. CONCLUSIONS

The major problem areas for tactical data systems in the 1970 era will be:

- Input/output equipment
- Very large capacity auxiliary storage
- Large-screen displays
- Concepts and philosophies for maintenance of batch-fabricated equipment

The impact of new technologies on Naval tactical systems will be profound. The use of these new technologies will provide:

Lower costs

Increased performance

Reduced size, weight, and power

Increased reliability and maintainability

The improvements that are expected in size, weight, and power requirements are illustrated by comparing present NTDS equipments with estimates for equivalent equipments that will be achievable in 1970. These comparisons, which are shown in Table 6, indicate a 25-1 reduction in the size and weight of a central processor and a 3-1 reduction in the size, weight, and power requirements of the overall data handling and display portions of the system.

It is not necessary to wait for the development of a complete new system to achieve some of these advantages. Some of them can be achieved within the next few years in an evolutionary manner by replacing individual equipments.

The studies being conducted by EMC^2 and Informatics are investigating requirements and applications for future data systems in the Navy. These studies will undoubtedly indicate increased performance requirements and new applications for future systems. However, even if no performance or application requirements existed for the development of a new system, the significant improvements that new technologies will make possible in size, weight, reliability, and maintainability will justify the development of a new generation of tactical data systems.

Equipment	No. in System	Present NTDS			Equivalent 1970 System			Total Reduction (No. X Difference)		
		Size Cu. Ft.	Weight Lbs.	Power Watts	Size Cu. Ft.	Weight Lbs.	Power Watts	Size Cu. Ft.	Weight Lbs.	Power Watts
AN/USQ20B Computer	3	51	2400	4500*	2	100	250	147	6900	6900
Magnetic Tape Unit	2	46	1400	2700	35	1100	2100	22	600	1200
Video Processor	2	46	1500	2100	4	200	400	84	2600	3400
Teletype & Adaptor	1	29	300	500	20	200	350	9	100	150
Paper Tape Unit	1	15	260	700	10	170	470	5	90	230
System Monitor Panel	1	14	400	240	7	200	150	7	200	90
Terminal Equip. Logic	1	32	1000	1400	3	100	200	29	900	1200
Keyset Central	1	32	960	1400	3	100	200	29	860	1200
Keyset Universal	8	3	100	200	2	70	120	8	240	640
MG Set	3	14	1000	1000**	5	300	150	27	2100	2550**
MG Control	3	11	320	----**	2	120	---**	27	600	----**
Interconnection Panel	8	14	250	----	0.5	20	---	108	1840	----
Central Pulse Amp	1	27	630	390	12	300	200	15	330	190
Symbol Generator	1	32	700	680	4	150	150	28	550	530
Display Console	12	32	1200	1400	16	500	600	192	8400	9600
Totals for Typical Systems		1113	38410	49810	376	12100	16080	737	26310	33730

* Includes 2000 Watts required to run the blowers

** Power input to MG Set and MG Controller in excess of that delivered to the computer

COMPARISON OF EQUIPMENTS OF TYPICAL NTDS SYSTEM

WITH EQUIVALENT PERFORMANCE EQUIPMENTS FEASIBLE IN 1970

Table 6