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This title Computers and Defence Applications was published in the year 1991.

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Popular Science & Technology Series

Editor PST Copy

Computers and Defence Applications

Second Edition

Defence Scientific Information & Documentation Centre
Defence Research & Development Organisation
Ministry of Defence, Delhi-110 054.

Popular Science & Technology (PST) series is a half-yearly publication of DESIDOC to promote knowledge and understanding of the applications of science and technology in Defence among Defence personnel, students and the general public. The presentation is lucid and generally in non-technical language. The text is supported by figures, photographs and cartoons. Each issue is devoted to a subject of topical interest.

Second Edition 1991.

Editor's Copy

Computers and Defence Applications

ISSN 0032-4639

Second Edition

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To

VEENA

Who Endured my Infatuation
With Computers for Twenty Five Years
and
Still Continues...........

Foreword to the Second Edition

Computers are playing a major role in all high technology areas, especially in aerospace and Defence applications. The recent Gulf war has amply demonstrated the impact of using computers in improving the performance of weapon systems. The use of computers in all activities of human beings for betterment of their living conditions cannot be over-emphasised. With tremendous improvement in computer technology, the miracle chip is affecting every person on this planet.

During DEFCAP-86 Seminar organised at DRDL, Hyderabad in November 1986, the potentialities of computer technology were highlighted and shared among computer specialists and other professionals. In the panel discussions, it was stressed that an all-out effort must be made to expose a larger strata of our community both in the civil and the Defence sector to the computer revolution. During DEFCAP–88, further exposure to Defence applications of computer technology was made.

I am glad that the first edition of Popular Science and Technology Series issue on 'Computers And Defence Applications' had an overwhelming response. The booklet had been well written in simple terms avoiding all the jargon, usually associated with high technology.

Based on the intensive discussions held in the Science Council of DRDL on 9 April 1991, Brig RK

Bagga has added one new chapter on 'Information Technology in the High-Tech War' in this edition. The second edition is well-documented by inclusion of sketches/photographs, to give an insight into the role of computers in Defence applications.

I am sure this revised edition will have wide circulation among the young students and novices, who will find it very informative.

Dr APJ Abdul Kalam
Director
DRDL/RCI

Hyderabad
29 May 1991

Preface to the Second Edition

I was overwhelmed with the response to the first edition of the issue of Popular Science and Technology Series on 'Computers and Defence Applications'. In fact, I received hundreds of letters and a number of them from remote areas of the country, where this cheap edition had found readers. Meanwhile, there was a strong plea by the computer users' community to come out with a translation of this issue in regional languages, when it is revised.

The predictions made in the first edition, particularly in Chapter 5, have nearly come true as demonstrated by the computerised weapon systems used during the recent Gulf war. The ever-changing computer technology has surpassed all earlier predictions and has established itself as the single most powerful technology in all activities of human endeavour. Thus, a need was felt to update the first edition by incorporating the improvements in Defence weapon systems envisaged during the next decade.

I have tried to revise all the six chapters by carefully omitting the obsolete material and adding new one wherever relevant. A comprehensive chapter on 'Information Technology in High-Tech War' giving a number of examples of usage of computers in various weapon systems has been added. The chapters on 'Future Trends and Military Implications' and 'Indian Scenario' have been rewritten.

DESIDOC has made efforts to get the new edition of this special issue translated into Hindi. This should meet the requirement of a large number of Hindi knowing users, who want to make a career in this dynamic area of computers and thus contribute in Defence preparedness of the country.

I hope this edition also will find acceptance amongst the computer users in the country, in particular, those working in Defence establishments.

Brig RK Bagga
Director, Computer Centre
DRDL

Hyderabad
29 May 1991

Preface to the First Edition

Computer technology has brought about a new information revolution in the world. The availability of cheap Personal Computers (PCs) has brought this revolutionary tool within easy reach of individuals. The computer has ceased to be only a sophisticated tool in the hands of few specialists. It is finding applications in almost every domain of man's activities. Defence is a major beneficiary of this 'computer explosion'.

A first ever Seminar on 'Computer Applications in Defence (DEFCAP 86)' was held at Hyderabad in November 1986. The objective of the Seminar was to share the experiences of the computer users and computer professionals in the vital areas of Defence applications. The participants were unanimous about the need to share this new technology within and outside Defence, so as to derive maximum benefit for the country.

When Shri SS Murthy, Director, DESIDOC approached me to compile this special issue of Popular Science and Technology, I gladly accepted the offer. With the help of this popular journal, I would be able to fulfil the trust reposed in me by DEFCAP-86 of spreading the 'computer culture' to all levels. In this special issue, an effort has been made to give a layman's view of the computer technology and Defence applications, in simple language, with particular reference to India. To do full justice to this complex and ever-changing computer field, in this limited volume, has been a major challenge.

After a brief historical background in Chapter 1, the fundamentals of computer systems are covered in Chapter 2. Chapter 3 is fully devoted to the area of software for mainframes, minis and Personal Computers. The current applications of computer technology in the world, in the areas of direct interest to Defence Services, are covered in Chapter 4.

It is very difficult to make any prediction in this volatile computer technology; however an effort has been made in Chapter 5 in crystal-gazing on Military implications of the Fifth Generation computers and 'Star Wars' programme of the USA. The concluding Chapter 6 highlights the computer scenario in Indian context, with particular emphasis on Defence Services and Defence Research and Development Organisation. For readers normally foxed with computer jargon, a glossary of common computer terms has been included.

The entire issue is based on published literature and an effort has been made to compile this publication on Personal Computer. The assistance provided by Ms P Radhika in compiling this issue is thankfully acknowledged.

R K Bagga

Acknowledgements

This is to acknowledge the contributions of a large number of readers of the first edition of the PST series issue on 'Computers and Defence Applications', who had written to me and given valuable suggestions. In particular I am grateful to all the students of Phase II Orientation Course for Computer Scientists conducted at DRDL/RCI who had given chapter-wise comments on the book. The contributions of Amit, Rajasree and Sanjay, who pointed out the various spelling mistakes in the first edition is acknowledged with thanks.

Dr SS Murthy, Director DESIDOC and Chief Editor, and Mrs Anuradha Ravi, Editor, have been instrumental in bringing out the second edition, as well as its Hindi translation, in a very a short time. The efforts of Dr CL Garg of Defence Science Centre, Delhi in undertaking the Hindi translation of the issue considering the difficulty in finding equivalent technical terms is really commendable. This is to place on record my sincere thanks to them for their special assistance. Prof S Sampath (now at Puttaparthi) has been a source of inspiration right from DEFCAP-86 days in encouraging me to document this computer knowledge for use by the general public and had written the Foreword to the first edition. Dr APJ Abdul Kalam, Director DRDL/RCI has given valuable suggestions, specially in the formulation of Chapter 5 on High Technology. He was also kind enough to

write the Foreword to this second edition. I am indebted to both of them.

The correction of the manuscript of the second edition has been a marathon task. In this I was ably assisted by Mrs Vandana Kaushik, Mrs Shakuntala Sharma, my father Shri HR Bagga and in the final stages, by my wife, Veena. I admire their patience in going through line by line and pointing out from a layman's angle, the technical portions not likely to be understood. Mohd Rasheed deserves thanks for helping me in preparing various sketches which have gone into the second edition.

This entire work of updating the first edition and inclusion of a new chapter has been made possibe by the untiring effort of Mrs P Radhika, who has smilingly worked for long hours on PC for over two months, including holidays, to complete this time-bound task.

Hyderabad
29 May 1991

Brig RK Bagga

Contents

Common High-Tech
Abbreviations Used in Gulf war

AFATDS	– Advance Field Artillery Tactical Data System
ALARM	– Air Launched Anti Radiation Missile
ASAS	– All Source Analysis System
ATBM	– Anti Tactical Ballistic Missile
ATCCS	– Army Tactical Command and Control System
AWACS	– Airborne Warning And Control System
CEP	– Circular Error Probability
CSSCS	– Combat Service Support Command System
DSCS	– Defence Satellite Communication System
DSMAC	– Digital Scene Matching Area Correlator
ELINT	– ELectronic INTelligence
EOGB	– Electronic Optically Guided Bomb
FAADSC^{2}I	– Forward Area Air Defence System Command Control and Intelligence
FLIR	– Forward Locking InfraRed
GPALS	– Global Protection Against Limited Strikes
GPS	– Global Positioning System

HARM	– High Speed Anti Radition Missile
JSTARS	– Joint Surveillance and Target Attack Radar System
JTF	– J●int Tactical Fusion
JTIDS	– Joint Tactical Information Distribution System
LANTIRN	– Low Altitude Navigational and Targeting Infrared Night
LGB	– Laser Guided Bomb
LPI	– Low Probability of Intercept
MCS	– Manoeuvre Control System
MILSTAR	– MILitary Strategic and TActical Relay (Satellite)
NAVSTAR	– NAVigation Satellite Timing And Ranging
PAWS	– Phase Array Warning System
PGM	– Precision Guided Munition
PLRS	– Position Location Reporting System (10 m)
SEP	– Spherical Error Probability
SIGINT	– SIGnal INTelligence
SLAM	– Stand Off Land Attack Missile
SLCM	– Sea Launched Cruise Missile
TACAMO	– TAke Charge And Move Out
TERCOM	– TERrain COntour Matching
TLAM	– Tomahawk Land Attack Missile
TMDI	– Tactical Missile Defence Initiation
TVM	– Track–Via–Missile
WWMCC	– World Wide Military Command and Control System

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1

Abacus to Computers

INTRODUCTION

Man has been devising tools to aid him from ancient times. Primitive man used his fingers for counting. When the need arose, he made use of pebbles, sea shells and beads to keep an account of larger numbers. Over 5000 years ago, the Chinese made use of the abacus, a clay board with a number of grooves in which pebbles could be placed. The pebbles could be moved from side to side for counting The materials used have changed, but the basic principle has remained the same. The modern abacus (Fig.1.1) has several rows of beads strung on wires in a rectangular frame. It assists in counting in the decimal system.

With the availability of metals, a number of mechanical gadgets were made for easier calculations. When electricity was discovered, these were replaced by electromechanical devices. In the twentieth century, electronic devices have helped scientists and engineers in ushering in a new era—the era of computers. Like its predecessors, the computer still remains a 'tool' (though a very sophisticated and powerful one), in the service of mankind. Modern computers are also called Electronic Data Processing machines or EDP machines, as these electronic devices act on raw data fed into them and process the same in specified ways. The processed data in a usable form is termed as 'information'. Computer and communication play a key role in providing up-to-date information; and the technology employed is often called Information Technology (IT).

HISTORICAL BACKGROUND

Calculating machines were the forerunners of the computer. Blaise Pascal developed a model calculating machine in 1642 to assist his father in tax office work. The machine consisted of rows of toothed wheels, which could add eight-column numbers. It could perform carry-over function automatically. The machine was further improved by Gottfried Wilhelm Von Leibniz in 1673 to perform subtraction, multiplication and division, apart from addition. In the beginning of the nineteenth century, Joseph M Jaquard developed an automated weaving loom. He used a punched card system to produce different patterns.

In 1812 Charles Babbage, a British scientist and mathematician, built a machine to produce mathematical tables. Since it was based on the theory of differences, he called it the 'Difference Engine' (Fig.1.2). He later conceived the idea of an 'Analytical

Engine', which could perform all the four arithmetic operations, find square roots, calculate percentages and could also control itself. He wanted his machine to have the capacity to make decisions, to skip some steps, and to perform repeated operations.

Babbage is considered to be the father of the present- day computer, as he gave the concept of 'stored program'. A program is basically a set of instructions to be followed in a sequence. His machine also had a memory. Babbage's Difference Engine was very similar in concept to the modern computer, but it could not be made during his lifetime as the technology had not developed to that extent. The ideas were ahead of their time, and working computers had to wait till the electronics arrived in 1940s. The scientists at the Science Museum in London have completed the Difference Engine in 1991 to study if it could have performed those functions, had Babbage succeeded in making his machine and have found that it does work ! The Engine is on display as a part of an exhibition organized to mark the 200th year of his birth.

Though his Analytical Engine was never built, he wrote detailed letters about it to Ada Augusta Lovelace (Fig 1.3), Lord Byron's daughter. She had written several programs for it. She is considered as the first programmer in the world, and ADA, a modern computer language, has been named after her.

In 1944 Howard Aiken of Harvard University developed an electromechanical computer called Mark I. It had different parts of a unit record system wired together and controlled by a roll of punched paper tape. It was the first fully electronic machine though the registers used for storage were operated mechanically. The first fully electronic computer was completed in 1946 by J Proper Eckert and John Mauchly. This computer was called ENIAC—Electronic Numerical Integrator And Calculator. It used high speed vacuum tube switching devices. It had a memory to store data and was designed mainly to calculate the trajectory and range for the artillery shell for the Army. ENIAC was faster compared to earlier machines. It could add two numbers in 200 microseconds and multiply two numbers in 2800 microseconds. It used 19,000 vacuum tubes and occupied an area of 150 sq m.

John von Neumann gave the concept of 'stored program computer', where the instructions could be stored along with data in the computer. The first stored program computer EDSAC (Electronic Delay Storage Automatic Calculator) was built by Maurice Wilkes in 1949.

During the last four decades, computer technology has made remarkable progress. The modern computer is 10,000 times cheaper, a million times faster and far more reliable than the earliest computer. *If the automobile technology had made similar* progress, a car would now be as cheap as this PST issue, more powerful than any train, could go round the world 25,000 times on a tankful of petrol and would be so small that one could park six of them on a full stop!

GENERATIONS OF COMPUTERS

Computer technology has gone through four generations since the first computer was demonstrated. The generations are based on the evolution of electronic technology, as electronics has a direct impact on the development of computers.

First Generation

Computers developed during early 1950s were characterized by the use of the vacuum tube as the principal electronic component. The machines were quite large, generated considerable heat and broke down quite frequently. The speeds of first generation computers were measured in milliseconds. These computers had limited internal storage. These were punched card systems, used mainly for scientific applications.

Second Generation

Computers developed during late 1950s using solid state electronic components (transistors) in place of valves are classified as second generation computers. Use of transistors resulted in size reduction, less heat generation and increased reliability of the systems. It also increased the storage capacity, computational speed and improved the input/output time. Speeds were measured in microseconds. These computers used magnetic tapes along with cards. Separate systems were developed for business and scientific applications.

Third Generation

Computers developed in mid-1960s characterized by the use of Integrated Circuits (ICs) in place of transistors formed the third generation. Using a more sophisticated fabrication technology, electronic circuits comprising separate interconnected components could now be manufactured as a single unit on a small silicon chip. Initially, ICs had ten transistors on one chip and these were called SSI—Small Scale Integrated—circuits. These were succeeded by Medium Scale Integrated(MSI) circuits having about 100 transistors per chip. This development further improved the memory capacity, computational speed and I/O (Input/Output) time of the computers. Speeds were expressed in microseconds/nanoseconds. There was considerable versatility in I/O devices and the software. Interactive working in timesharing and multiprogramming was made possible. In India, several third generation systems are still in use, like TDC-316, ND-570, etc.

Fourth Generation

The present-day computers appear to have evolved in a more gradual manner and are discussed in detail in the next section under computing systems. Apart from using higher level of integration, this generation has led to novel hardware devices for input/output and versatile and powerful software provide the power. LSI (Large Scale Integration—1000 gates) and then VLSI (Very Large Scale Integration—10,000 gates) have led to further miniaturization in size and improved the speed of computers. In 1971 Intel Corporation of USA introduced a microprocessor, which contained the entire Central Processing Unit (CPU) of a small computer on a single chip. More and more powerful microprocessors have since been made and form the basis of present-day microcomputers.

Microprocessors Microprocessors fulfil the complete requirements of the CPU on a single chip. The power of a microprocessor is determined by its word size and its clock frequency. The word size governs the width of computer data path, which provides the accuracy of computation and affects its power. The frequency of its electronic clock decides its speed, which is synchronized for various computer operations. The trend in microprocessors is towards a larger word size and a higher clock frequency. As the word size increases an operation can be completed in fewer machine cycles. With increased clock frequency, there are more cycles available per second for performing various functions. The first generation of microprocessors started with 8-bit word length, which were replaced by 16-bit microprocessors in the next generation. At present 32-bit microprocessors are commonly in use in most of the microcomputers. The level of electronic integration is greatly increasing and it is now possible to accommodate nearly thirteen lakh gates on a single microprocessor chip. Figure 1.4 depicts microprocessors belonging to the Intel and Motorola families and their progress during the last decade. Word length has increased to 64 bits; and clock speeds of 50 MHz are available, and 100 MHz have been announced for realization in the near future.

Fifth Generation

In 1981, Ministry of International Trade and Industry, Japan, took a major policy decision to undertake development of a new generation of computers, called the Fifth Generation. ICOT—Institute of Computer Technology—was established with major funding from Japanese Government and industry. The machine will have an intelligent user interface so that a very large group of people can use it. The machine is to be based on Artificial Intelligence (AI) concept. Figure 1.5 shows the architecture of the fifth generation computer system, as originally planned.

The hardware aims at using VVLSI (Very Very Large Scale Integration) providing over a million gates per chip, capable of logic processing. It is aimed to achieve a speed of one million LIPS (Logical Inferences Per Second) using PROLOG language. The computer system will have natural language interface, using Knowledge Information Processing System (KIPS) and problem-solving software. To counter Japanese efforts the USA and Europe had also taken up major time-bound programmes to develop major AI based computer systems. A number of expert systems using the new technique have started appearing for various applications.

Table 1.1 gives an idea about units of time in relation to real-life situations. From this, readers can get an idea of computer speeds.

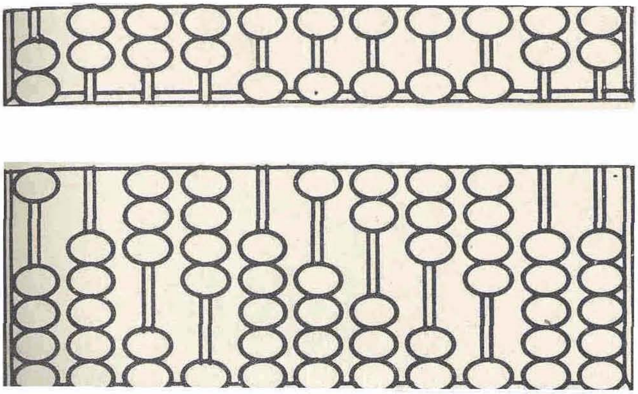

Fig. 1.1 Chinese abacus

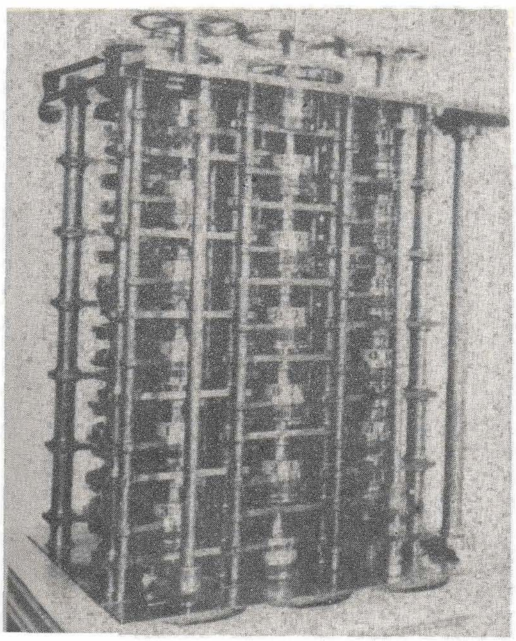

Fig. 1.2 Difference engine

Fig. 1.3 Ada Augusta, the first programmer

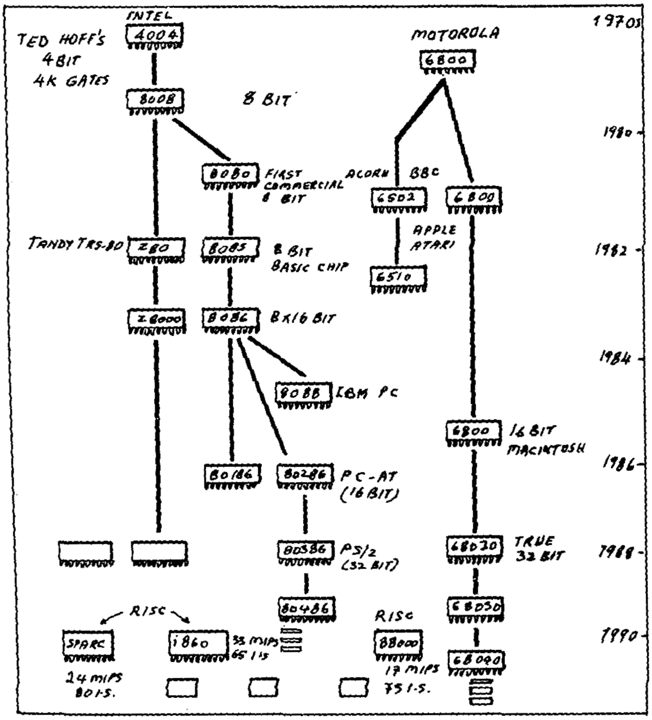

Fig. 1.4 Microprocessor families and their progress during the last decade

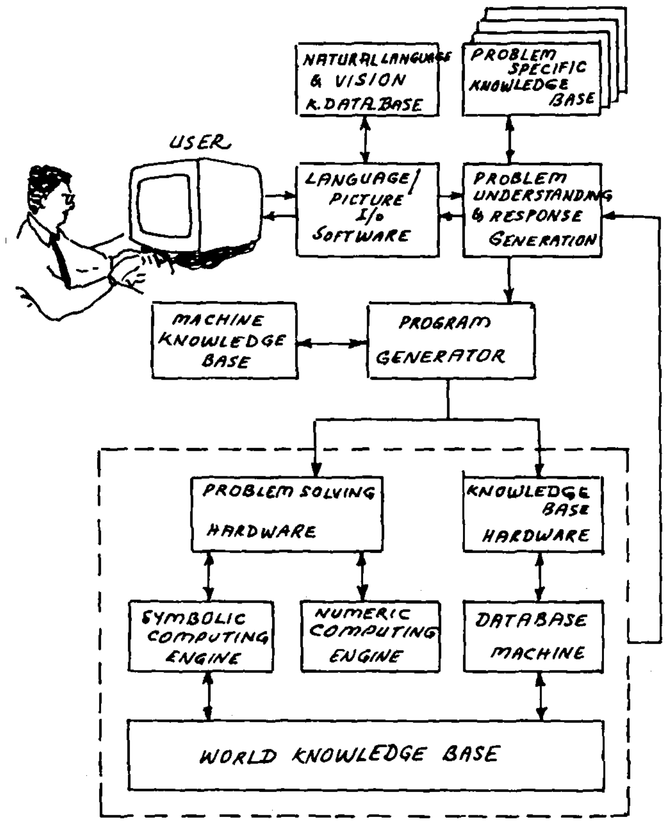

Fig. 1.5 The basic design of fifth generation computer system as envisaged by Japanese

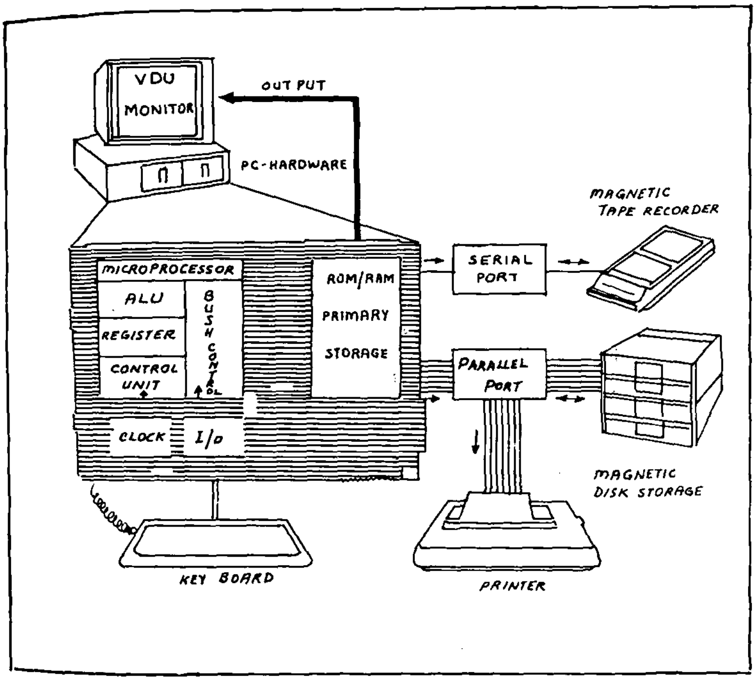

Fig. 1.6 Anatomy of a typical Personal Computer

Table 1.1 Units of time and real-life activities

Unit of time	Part of second	Real-life activity
Millisecond (ms)	One-thousandth (1/1000)	A baseball pitched at a speed of 95 mph would move less than 5 cm in this time
Microsecond (μs)	One-millionth (1/1000,000)	A spaceship travelling at 100,000 mph would move less than 5 cm in this time
Nanosecond (ns)	One-billionth (1/1,000,000,000)	There are as many nanoseconds in one second as there are seconds in 30 years, or as many nanoseconds in a minute as there are minutes in 1,100 centuries
Picosecond (ps)	One-trillionth (1/100,000,000,000)	Electromagnetic waves travelling at 180,000 miles/second would move less than 1/50th of an inch in a picosecond. A picosecond is to a second what a second is to 31,710 years

COMPUTING SYSTEMS

Based on their size and computing power, the present-day computers can be grouped into various classes, such as super-computers, mainframes, minicomputers, microcomputers and personal computers.

Supercomputers

Supercomputers are the most powerful systems available and are primarily being used for special scientific and military applications. CRAY is the best-known example of the supercomputer being made in the USA. NEC of Japan has also recently made the SX series of computers capable of performing 1300 Million Floating Point Operations Per Second (MFLOPS). The cost of a supercomputer is of the order of Rs 10-15 crores per system and there are less than 150 such systems installed in the world at present. These computers are increasingly being used for applications in nuclear physics, meteorology and for solving complex computational problems in fluid dynamics, apart from military applications. In India, the only supercomputer, Cray X-MP 14, is being used for weather forecasting.

Mainframe Computers

Mainframe computer systems form the bulk of computer installations in the world. Most organizations are using these computers capable of carrying out up to ten million instructions per second for various data processing and scientific applications.

Typical mainframe systems cost from Rs 50 lakhs to Rs 5 crores, depending on their configuration. Mainframe computers are multiuser facilities and support a large network of terminals and remote job entry stations, i.e., these are master computers with large computing capacity to which several microcomputers, minicomputers and terminals can be connected. Most scientific computations in academic institutions and laboratories are being performed on mainframe computers. Large commercial and industrial establishments and Government agencies use these systems for information storage and retrieval.

Minicomputers

Minicomputer systems are medium sized computers which are smaller, slower and less expensive than mainframes. Minicomputer systems can perform the tasks of mainframe systems but at a reduced scale. These can also be used to support a network of user terminals and can act as concentrators. Minicomputers are, by and large, giving way to more powerful supermini systems, having computing potential comparable to earlier mainframe systems.

Microcomputers

Microcomputers are the smallest, cheapest and the most common computer systems now available. As mentioned earlier, microcomputers get their name from the fact that their main computing component is the microprocessor. The mini and mainframe computers use complex electronic circuitry for performing the functions of the central processing unit whereas, in microcomputers, a single microprocessor chip provides the complete CPU.

Personal Computers

Personal Computers (PCs) are basically microcomputers, originally meant for day to day personal applications of individuals. These are stand-alone systems providing a wide array of capabilities. PCs have revolutionized the computer technology and have brought its fruits within easy reach of the common man. With improvement in processing capabilities the PCs are now capturing the domain earlier occupied by mini and mainframe systems.

ANATOMY OF A PERSONAL COMPUTER

The typical anatomy of a present-day PC is given in Fig. 1.6. It includes the hardware consisting of the microprocessor-based CPU and the various devices for storing information and for communicating with the users. In most microcomputers, a set of parallel conductors called 'bus' connects the main components. The processing unit is the microprocessor supported by various auxiliary chips to perform various functions. Information can be entered into the system through a keyboard. Pressing a key generates a coded signal unique to the key; the code is stored in the display memory and appears on Cathode Ray Tube (CRT) display. The primary memory, which consists of semiconductor memory chips holds programs and data currently in use. The memory can be accessed randomly and its contents can be changed rapidly. Disks and magnetic tapes which are secondary memory devices, generally have a much larger storage capacity but are slower. A block of information can be retrieved from the disk and processed by the microprocessor to reduce delay.

The different interfaces connect the computer to other devices such as a printer or a modem, short for modulator demodulator (to give access to telephone system). In a serial interface, the information is transferred one binary digit (bit) at a time, as against parallel interface, where multiple conductors carry several bits of information simultaneously. The bulk of present-day PCs are IBM PCs based on modified 16-bit Intel 8088 microprocessor which has 8-bit data path but data is processed 16 bits at a time internally. Disk Operating System (DOS) has also become the de facto standard, providing the user various commands for efficient management of the hardware.

DEFENCE APPLICATIONS

The Defence Services have always been catalysts in technology development from the early days of gunpowder. Computers have been applied in all areas of Defence throughout the world. More and more use of computerized weapon systems is being made by the advanced countries, thereby making them more effective. On ground, in air and under water, computers have found innumerable applications in Defence. The prime objective of this special issue is to highlight modern computer technology and its applications in Defence with special reference to India.

2

How a Computer Works

GENERAL

The heart of the computer is made up of thousands of ICs, transistors, resistors, capacitors, diodes, etc. It works on a system of binary numbers and Boolean algebra. The computer receives information in the form of electric pulses, interpreted as a series of codes of 1's and 0's. These 1's and 0's which can be compared to the ON and OFF states of a bulb, are called *binary digits* or bits. Codes for all numbers, alphabets, symbols like =, +÷ –, ? can be made by combining these bits. A group of bits is called a byte (usually eight bits).

George Boole, a British logician and mathematician used algebra to represent logical statements. With this, it is possible to reduce all problems to a series of questions which can be answered YES or NO and can be represented by 1's or 0's. A set of three logical functions called AND, OR and NOT are all that are basically required to process these 1's and 0's. These functions can be performed electronically by suitable combinations of transistors, resistors and capacitors and are called logic gates. These logic gates are the constituents of Arithmetic Logic Unit (ALU). These are also combined to make other circuits called flipflops, latches, registers, etc. which perform other functions.

COMPUTER CONCEPTS

Stored Program

The working of the different parts of a computer can easily be understood by referring to Fig. 2.1. The Control Unit serves to direct and sequence the operations. The ALU performs the arithmetic operations and the logical comparisons inherent in the computer program. Both the program and the data are kept in the store or internal memory. This is the concept of 'stored program' given by Von Neumann.

Working Principle

A word in computer memory normally stores a fixed length of bits. It can store either a computer instruction or data. The contents of the word is in the form of codes to represent alphabets, numbers, or special symbols. A common code used for this purpose is the ASCII (American Standard Code for Information Interchange) code. An instruction stored in the memory consists of two parts, the operation to be performed (OP code) and the address in memory, where the operation is to be performed. The control unit is responsible for decoding the OP code and getting the necessary operands from the memory, for carrying out the operation. For this purpose, control registers called OP code Registers (OPR), Memory Address Registers (MAR) and Instruction Counters (ICs).are used.

The computer operates in two phases. In the first phase, the list of instructions (program) is read and stored in the memory. The end of the program is specified by a specially coded instruction. Data follows this instruction and is not read during this phase.

During phase two, the control unit fetches the first instruction stored in the memory. The OP code is entered in the OPR and the address part of the instruction in MAR. The instruction counter is increased by one, to point to the next instruction. The OP code is decoded and controls are activated to execute the current instruction. Thus, one by one, all the instructions of the program are executed, till the end-of-job (EOJ) instruction is encountered and then the computer stops.

Central Processing Unit (CPU)

The CPU controls and supervises the functioning of the entire computer system to perform all its arithmetic and logical operations. CPU uses I/O paths called channels for carrying out control operations over different I/O (Input/Output) devices. The control section is the overall coordinator of system operation. It governs I/O operations, data transfer to and from storage, and guides the routing of data between storage locations and the ALU. The important function is carried out in what is called the 'fetch-execute cycle'. It fetches an instruction from the main storage, interprets it and carries out the necessary execution by sending command signals to the appropriate hardware circuitry. For example, the control section may start or stop a printer or the disk drive.

The ALU is provided to carry out arithmetic (+ , -, *, /) and logical operations (AND, OR, XOR, NOT) on the operands. The basic circuitry calculates and shifts numbers; sets the algebraic size of the result and rounds off the decimal position. The logical circuitry of CPU makes certain decisions based on the set of conditions that the programmer writes. When these conditions are present, it changes the sequence of the instructions to be carried out depending on the operation used. Figure 2.2 gives the schematic layout of a typical CPU.

Registers are devices which are capable of receiving data, holding it and quickly transferring it for further computation. Registers have same bit positions as the main storage locations and can be accessed very quickly. Certain registers like the accumulator keep the intermediate results, whereas different storage registers contain information being sent to or from the main memory. The address registers hold the address of the locations of main store, whereas the operation code register holds the operation code part of the instruction that is being executed. There are other general purpose registers, which are used to assist programmers in speedy execution of their programs.

Primary Memory

There are two kinds of primary memories—Read Only Memory (ROM) and Random Access Memory (RAM). Read Only Memory is basically for information that is 'written in' at the factory and is to be stored permanently. It cannot be altered by users normally. For a single application computers such as word processors, the information in ROM might include the application program. In case of versatile PCs it includes most of the system programs which can be used for various applications. As the cost of ROM is dropping, there is a tendency to include more and more system programs in ROM, rather than in secondary media. Random Access Memory is also called Read/Write Memory, because the new information can be written in and read out, as often as it is needed. RAM chips store information, both programs and data, that are changed from time to time. For example, a program for a particular application is read into RAM from a secondary storage disk. Once the program is in RAM, its instructions are available to the microprocessor. A RAM chip holds information in electronic cells as long as it has power. There are different varieties of RAMs and ROMs depending on their particular applications. Table 2.1 gives a summary of some of the major types of memories and their typical applications.

Table 2.1 Different types of memories and their typical applications

Memory type		*Application*
Random Access Memory (RAM)	Dynamic RAM	Main memory storage device for mainframes, minicomputers and PCs
	Static RAM	Microcomputers requring a small storage capacity, high-speed versions for minicomputer buffer storage; low-power versions for portable computers
Read Only Memory (ROM)	ROM	Program storage for PCs, character set storage for visual displays and printers
	PROM	Microprogram control instructions for minicomputers; military and automobile uses
	EPROM	Same as for ROM. Ability to reprogram makes it easier to correct errors during software development
	EEPROM	ROM & EPROM applications needing occasional program or data modifications

Secondary Storage

In larger computer systems, the information is stored on secondary storage formed by a number of magnetic disks. These disks are similar to phonograph reçords but there are no grooves. The data is stored on disks in a number of invisible concentric circles called tracks. These tracks, like the rings in a tree, begin at the outer edge of the disk and continue towards the centre without ever touching. Each track has a designated number of sectors. A motor rotates the magnetic disk at a constant speed of normally 3600 revolutions per minute (rpm). Data are recorded on the tracks of a spinning disk surface and read from the surface by one or more read/write heads. Figure 2.3 shows the arrangement of read/write heads and the recording surfaces on a hard disk.

Hard disks, which were fairly expensive, have now been replaced by cheap secondary storage floppy disks. A floppy disk can record large quantities of information on a flexible plastic disk coated with a ferromagnetic material. The floppy drive normally rotates at 300 rpm in a lubricated plastic jacket. An electromagnetic head is moved radially across the surface of the disk by a stepper motor to a position over one of the concentric tracks, where data is stored. The head can read or write by sensing the direction of magnetization and decoding the information. Though hard disks are capable of holding over 800 megabytes of information, the present-day floppy drives can keep over 640 kilobytes of information in

40-100 concentric tracks. Double sided disk drives provide twice the capacity using two heads, one on each side of the disk. Figure 2.4(a) shows a schematic diagram of a floppy diskette and Fig. 2.4(b) shows the major parts of a floppy drive commonly used withPCs.

Magnetic Tape

The most common external medium for storing historical information is the magnetic tape. A magnetic tape is a long plastic ribbon usually 1/2 inch wide, which is coated with magnetizable iron oxide material. Data can be recorded in the form of magnetic spots on the surface of the tape, as is done normally for voice recording in audio tape recorders. Magnetic tape is a sequential medium for storing large amount of information, which can be accessed in sequence. The hard disk and the floppy .disk discussed above are random access devices and give much faster access as compared to magnetic tape drives. The time taken to read a record depends on the location of information in the spool of a magnetic tape. In case of hard disks the access time is about 30 milliseconds, irrespective of location of the data. With PCs it is also possible to interface a domestic casette recorder for simple personal applications, since magnetic tape drives are very expensive.

Input Devices

All computers including PCs need some mode for reading information into the system. *Keyboard* is the most common input device which is used with all computers (Fig. 2.5(a)). The keyboards, like conventional typewriters, follow the QWERTY pattern of placing of letters. Some keyboards are provided with special purpose keys for performing various functions like 'Shift', 'Scroll', 'Page up' and 'Page down'. In addition, for numerical-intensive applications the numerical keyboard is duplicated at a convinent location. *Mouse*, shown in Fig. 2.5(b), is one more input device nowadays used with all graphic workstations, as well as PCs. The mouse operates in conjunction with display of an arrow/cursor on the screen, whereby one can select any of the options in a given *Menu*. The positioning and selection of a particular option makes it far easier to work with a computer as compared to actually keying in all the commands through the keyboard. Figure 2.5(c) shows a light pen, which is also used to draw patterns on the screen specially designed for this purpose. The *light pen* provides an easy method of entering graphic data, where high accuracy is not required. A *digitizer* is required for entering accurate professional drawings.

Output Devices

The primary output device in a computer system is a *printer*. There are several types of printers, i.e., dot matrix, line, drum, chain and the latest, laser printers. A line printer prints one line at a time and has a speed of nearly 1000 lines per minute. Both drum as well as chain printers are commonly used with mainframe and mini computers. For PCs, dot matrix printers are used. The laser printer works on a principle similar to xerox machines and gives print-outs of whole pages at a time.

Another output medium for present day computers is a *visual display unit (VDU).* It is a conventional CRT, where the computer user can monitor the input as well as output data. A typical display monitor can be used to see 24 lines of text with each line having a maximum of 80 characters. Multicolour *pen plotters* can also be interfaced for keeping a permanent record of graphic outputs.

Graphics Workstations

At present very sophisticated video terminals capable of displaying graphs and pictorial data are becoming available for computer users with resolution of 1024 X. Monochrome as well as multicolour terminals provide a higher degree of clarity of displays, both for scientific and business applications. Pictorial information enhances one's understanding of solution of complex problems. Usually a pointing device like a light pen or a mouse attached to the graphic workstation is used for entering graphical information into the system. Figure 2.6 shows a high resolution graphic workstation along with a mouse for working with pictorial data.

COMPUTER COMMUNICATION

It is possible to connect computers through various communication lines to provide computer users access to infor- mation located at remote or far-off places. Figure 2.7 gives a sample data communication system connecting a remote station to the CPU through a front-end processor. Connecting equipment and software are called interface elements and are used to bridge the different physical and operating environment that exist between I/O devices and the central processor. A modem is used at both ends of data transmission channel to convert the digital pulses into analog pattern suitable for transmission over the telephone lines and vice versa.

For providing computing facilities to nearby work centres, the concept of a Local Area Network (LAN) has been evolved, wherein a large number of microcomputers and terminals can be connected to a host computer. Figure 2.8 shows a typical ring LAN connecting various work stations. A star LAN has a central controller and all network stations radiate out from the central node. For interconnecting different computer locations the concept of a Wide Area Network (WAN) has also been developed. It is possible to connect various PCs to one of the computer networks, thereby providing access to major resources available at remote sites. To interconnect a variety of computer systems, we require network protocols or conventions, which govern the transmission of information over communication lines. The International Organisation for Standardisation has developed a reference model called the Open System Interconnection (OSI), for this purpose, which forms the backbone of Office Automation (OA).

TECHNOLOGY UPGRADE

The computer systems have been subjected to constant technology upgrades made possible by availability of better techniques or devices as well as computing concepts. In fact, the extensive use of

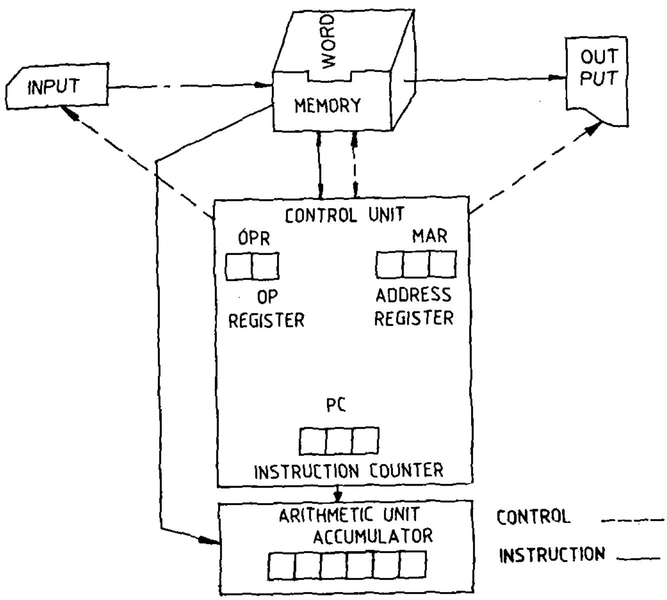

Fig. 2.1 Von Neumann architecture of computer

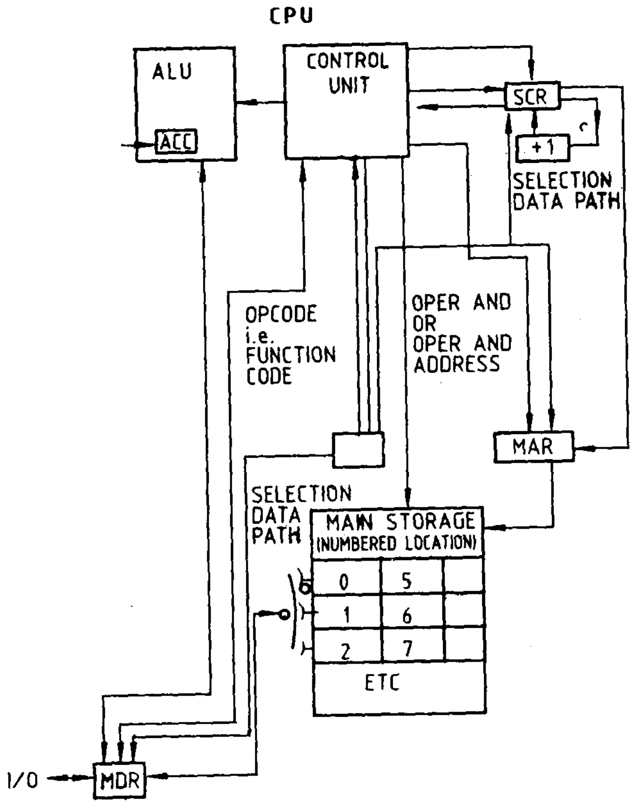

Fig. 2.2 Schematic layout of CPU

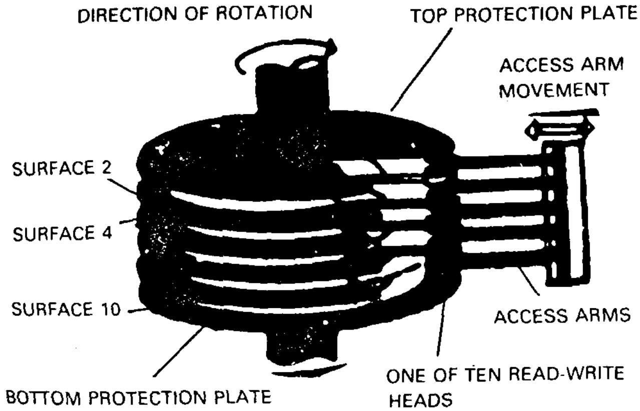

Fig. 2.3 Functional components of a hard disk drive

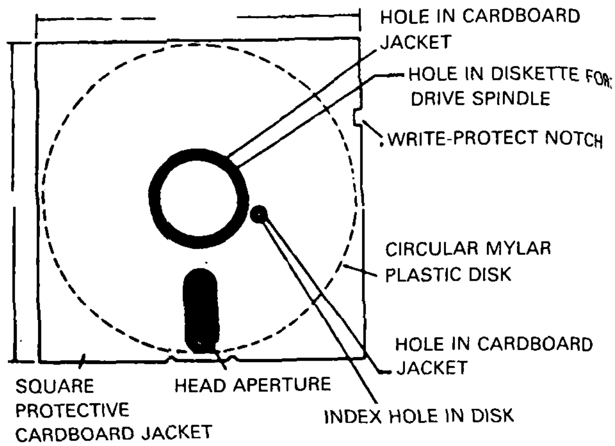

Fig. 2.4(a) Floppy disk

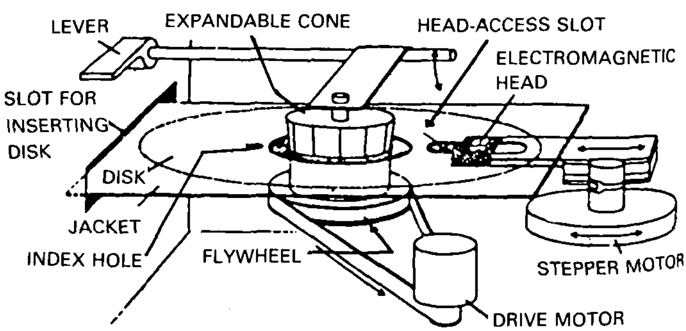

Fig. 2.4(b) Major parts of a floppy disk drive

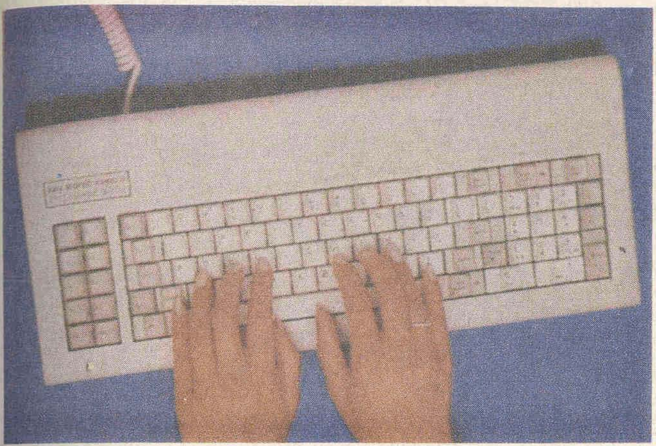

Fig. 2.5(a) The keyboard

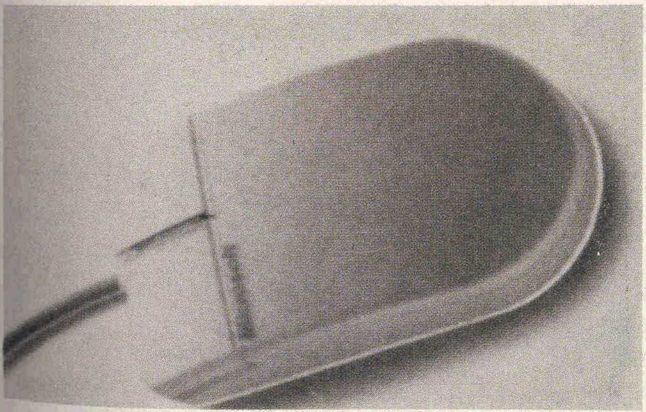

Fig. 2.5(b) The mouse

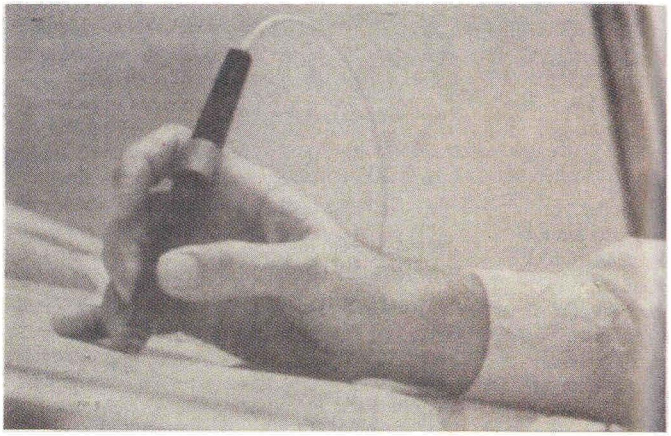

Fig: 2.5(c) A light pen is useful in graphic work to draw directly on the screen

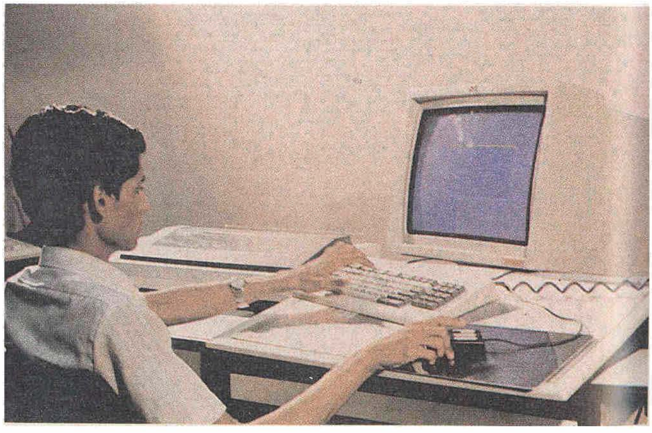

Fig. 2.6 A graphic workstation under use

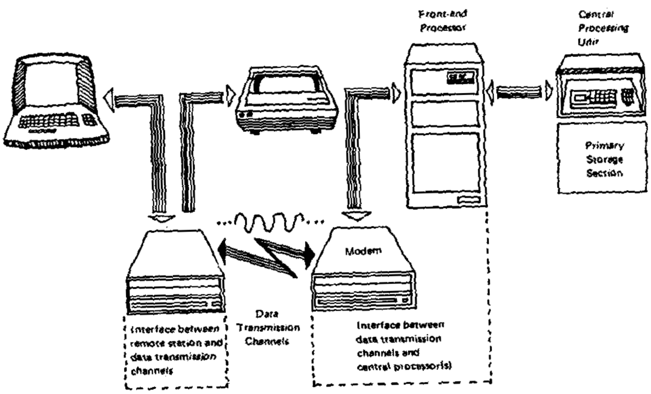

Fig. 2.7 Data communication system

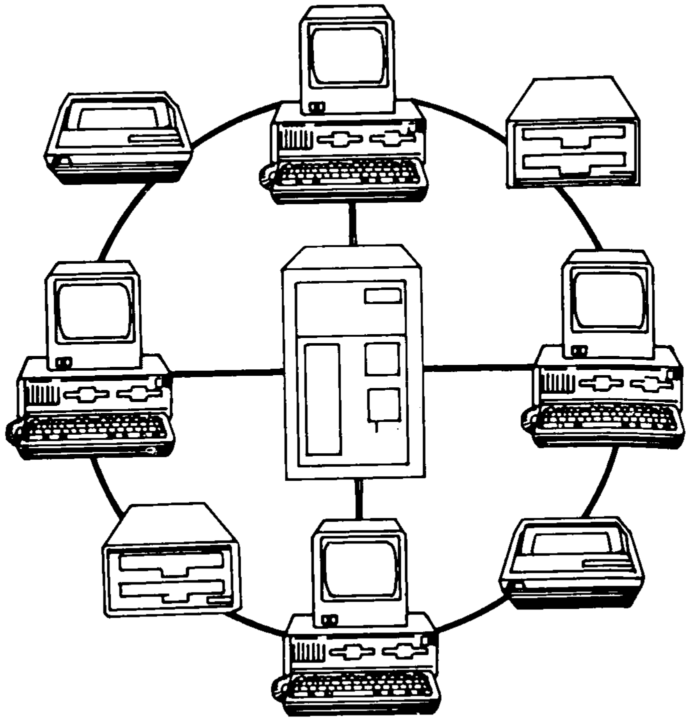

Fig. 2.8 Ring Local Area Network

computers in all fields has led to innovative technology, whereby a manifold improvement in various devices and their applications has become possible.

Advanced microprocessors. The silicon technology has revolutionised the component industry in electronics. Five micron technology has given way to 0.5 micron, thereby increasing thousand times the integration of number of gates on a single chip. The latest Intel i860 chip, normally called super micro, has 13 lákh gates to provide 64-bit internal and external databus and works with 40 MHz clock, giving a peak performance of 80 MFLOP in single precision. In fact, this type of power was only possible in supercomputers a decade ago. 100 MHz advanced microprocessors are likely to hit the market in the near future.

Transputers. A transputer is a high-performance processor, with memory as well as serial link, integrated on a single chip. Transputers are finding wide application in complex scientific computations because of their high speed floating point operation, as well as bidirectional communicational links for interconnecting the transputers in large numbers. Transputers are ideally suited for working in parallel processing environment. A special programming language called OCCAM is used for transputers. It is a block structured, high-level, parallel language, specially designed for transputers which allows various application programs to be decomposed into a collection of parallel processing tasks so that computing speed can be increased.

Reduced Instruction Set Computer (RISC). RISC is new sytle of computer architecture, which combines simplicity with efficiency to provide high-speed processing by computer. All conventional microprocessors have been using what is known as Complex Instruction Set Computer (CISC). The number of instructions in these microprocessors range from 300 to 400, depending on the complexity. The majority of these instructions were never used, except in some special applications consisting of development of real-time software. The RISC concept makes use of the philosophy that only essential instructions should be made available in hardware, thereby improving the processing power. Intel i860 has only 65 instructions. One of the new RISC chips used by a powerful graphic workstation is called SPARC. It has only 89 instructions and makes use of 136 registers to improve the performance. The RISC architecture is specially suited for high performance applications using high-level languages like ADA, C, PASCAL, LISP.

Parallel Processing

The basic Von Neumann architecture stored program computer is normally called Single Instruction Single Data (SISD) architecture. The power of SISD architecture has limitations depending on the electronic technology utilized. However, to improve throughput for certain typical applications like computational fluid dynamics, there is need to use a number of processors in parallel to obtain faster results. The following are two approaches which have been used in different computers for scientific computations.

Vector processing. The processor using the concept of Single Instruction Multiple Data (SIMD) is known as vector processing. In this, the same instruction has to operate on a large array of different data. Since a large number of processors are required, the improvement in speed comes at the expense of having extra hardware. CRAY series of supercomputers use such a concept.

Multiprocessing. The most common mode of obtaining high computational power at present is by using parallel processors in Multi Instruction Multiple Data (MIMD) machines. These computers consist of a number of independent processors, which communicate with each other and execute the program in parallel. Each of the processors forming part of the SIMD machine could be executing a different instruction depending on the problem. There are two special classes of parallel processors—one using shared memory called Tightly Coupled System; against the other called Loosely Coupled System. Ideally, each processor should be able to communicate with all others directly. This requirement has led to a large number of parallel processing topologies like hypercube, ring, etc. Since complete connectivity is not feasible, in a large number of processors a message passing protocol with limited connectivity is used to get optimal results. A number of parallel processing computers like cosmic cube, connection machine, buffer fly are commercially available at present.

During the past forty years, the developments in electronic technology has made available hardware for computer systems which are 1000 times faster and much cheaper than the initial ones. The various categories of computer systems have gradually merged and the present-day PCs are providing powerful computing services to the computer users. With the help of computer networks the enormous resources available with major computer systems can be accessed by computer users from their work place. Mainframe computers continue to assist them in day to day functioning.

3

What Makes Computers Work

GENERAL

The hardware of a computer provides the basic electronic and mechanical devices to perform various tasks, but it is the software which makes the computer system work. Hardware consists of the physical parts that one sees in any computer establishment, but the software is not visible. All types of computer programs which make a computer work are termed as software.

A computer program is the set of instructions which directs the operation of the basic machine hardware. The entire range of system programs designed to facilitate the operation of a computer system is called *System Software*. The programs written by users, which actually carry out data processing are called *Application Software*. System programming primarily consists of designing software for operating system, loaders, assemblers, compilers and a host of system utilities. The range of system and application software is very wide and only the essential aspects of these are discussed here.

SYSTEM SOFTWARE

Figure 3.1 shows the basic building blocks of system programming, which are essential for efficient utilization of a computer system by the computer users. From the users' point of view, the purpose of various system programs is to automate problem-solving in an efficient manner, with minimum intervention by the operators. A brief introduction of various system programs commonly available on all computer systems follows.

Operating System

An operating system is a system software usually provided by the vendor, which is responsible for efficient management of all computer resources. Figure 3.2 shows the various shells of an operating system for performing different tasks.

Processor management involves scheduling the various jobs which are required to be run on the system depending on their resource requirements and priorities. Processor management can be optimized by having timesharing, wherein the CPU's time is shared by a number of users at the same time. This is because the CPU works faster than the other units.

Memory management involves dividing the internal storage capacity of the computer between various programs. In a simple batch operating system, the memory resources are totally allocated to one program at a time. In multiprogramming environment, the memory is partitioned to serve a number of different programs simultaneously. There are different schemes to allot either fixed partitions or varying sizes of memory, depending on the design of the operating system. The present-day operating systems also provide virtual memory, wherein the size of the internal store is not a limitation for any program.

Input/output management helps in keeping track of various input/output devices, attached to the computer system. Depending on requirement, each I/O device is allotted to various tasks.

File management assists the computer in controlling a number of system and user files and their arrangement on secondary storage. The operating system relieves the user from the task of file manipulation on secondary storage.

The above mentioned functions are performed by the operating system program, which itself can be broken down into various elements. The most important is the supervisor or monitor. This is a resident program in the main memory and handles the entire system routines and calls upon other modules of operating system as and when needed by the application program. Figure 3.3 depicts the operating system as the chariot driver who controls the functioning of the entire computer system. Different computer system manufacturers provide their own version of operating system to perform the tasks. UNIX is one of the most popular operating systems available on a large number of mini and supermini computers. It supports multiuser, multiterminal applications, as well as concurrent processing of different applications. Written in C language, it is available across a fairly wide range of models and offers a very large set of utility programs necessary for efficient running of computer systems. For microcomputers MS DOS (Disk Operating System) developed by Microsoft Corporation, has become a de facto standard.

Assembler

Assembler is a system program which converts assembly program to machine language program. The basic hardware of computers can understand only the machine language, i.e., the language of 1's and 0's. Since assembly language makes programming slightly easier and understandable, more efficient programs can be written by system programmers. The assembly program is required to be translated by using the *assembler to generate machine level object code for* various assembly instructions.

Compiler

For higher-level languages like FORTRAN and PASCAL, a system program called *compiler* is required, which converts the high-level language to machine language for running on the computer system. The compiler is a complex system software, which carries out lexical analysis and syntactic analysis to produce object code in machine language for various high-level language sentences. Interpreter is also a system program which converts the high-level language into machine code, but works line by line, as against the compiler, which translates the entire source code in one go. Though inefficient, interpreters are still used in PCs for languages like BASIC.

Loaders

Most of the computer systems would need a system software to place the program in the appropriate location in the main memory and commence execution of the same. *Loader* is a system software provided by the vendors for loading the object code and executing the desired program. Bootstrap loader is a system software used for initial startup of computer system.

Utilities

Utility programs are general purpose system programs that can be used for many applications. SORT, MERGE, DEBUGGER are some of the common utilities provided by most vendors to assist the application programmer in getting his work done with ease.

COMPUTER LANGUAGES

There are basically three different types of languages used for computer programming. These are machine language, assembly language and high level language.

- **Machine language** is a language in which instructions are written in a series of numeric codes. This language is specific for each computer system and needs very careful coding.

- **Assembly language** is a language based on mnemonic codes for various instructions. There is one to one correspondence between assembly instruction and machine code.
- **High-level language** is a general purpose procedure-oriented language, which is machine-independent and makes the job of application programmer simple.

Table 3.1 gives a comparison of the three categories of the languages.

Table 3.1. Comparison of computer languages

Machine language	Assembly language	High-level language
Difficult to understand	Less difficult	Easy/convenient
Programming slow	Group task and code	Efficient for programming
Does not indicate job	Some indication	Easier documentation
Long, tiresome	Less tiresome	Easy
Not transportable	Not transportable	Transportable
Detailed knowledge of hardware	Register level hardware knowledge	No need of any hardware knowledge
Most optimal	So-so	Non-optimised
No library support	Limited library function	Library routines

Example

Let us take a simple example to understand these three categories of languages. Suppose we have to add two numbers and store the result of the same in computer memory. The machine instruction required for an 8-bit microcomputer along with equivalent assembly language instructions will be as given below

MACHINE CODE		ASSEMBLY LANGUAGE
0011	1010	
0110	0000	LDA X
0000	0000	MOV B, A
0100	0111	
0011	1010	LDA Y
0110	0001	
0000	0000	ADD B
1000	0000	
0011	0010	STA Z
0011	0010	
0110	0010	

A high-level laguage like FORTRAN will perform the same task by a simple statement Z = X+Y. In another English-like language COBOL, the statement will be 'ADD X TO Y GIVING Z'. Thus the higher-level languages provide a much simpler method for writing user programs. The machine-level language and assembly-level language have their own applications and Table 3.2 gives guidelines for appropriate use of the languages.

Table 3.2. Guideline for using computer languages

Machine language	Assembly language	High-level language
Low volume, small program	Small moderate program	Large program
Machine prototype	System software	More computation
Simple control application	Memory constraint	Application packages
Efficiency essential	Limited data processing	Time, memory no constraint

The main features of some of the important high-level languages commonly used are as follows.

- FORTRAN stands for FORmula TRANslation and is the oldest high-level language developed by IBM (International Business Machine Corporation) for scientific and engineering applications. Various versions of this language based on American National Standard Institute (ANSI) are available and the latest one is FORTRAN 8X.
- PASCAL was designed by Nikalus Wirth in 1971, primarily for beginners to learn efficient methods of problem solving. The language provides facilities for manipulation of numbers, vectors, matrices, strings of characters, etc. and is a good language for non-numeric programming.
- C Language was developed at Bell Laboratories and was used for designing the UNIX operating system. It is a favourite language of system

programmers and others who develop software packages for small computers.

- LISP (LISt Processing) primarily supports research in the area of AI. It is designed to manipulate non-numeric data and is extensively being used for AI and knowledge-based systems.
- COBOL stands for COmmon Business Oriented Language and is the most common language for data processing. At present COBOL-74 version is being used in most of the business applications.
- BASIC (Beginners All-purpose Symbolic Instruction Code) was designed with the specific goal of enabling beginners to learn programming quickly, using terminals. BASIC is the most popular language of all for the PC users.
- PROLOG is a relatively new AI language that has been chosen by the Japanese to be the standard language for their fifth generation computer project.
- SNOBOL (StriNg Oriented symBOlic Language) is a text manipulating and information retrieval language used by researches in the field of humanities.
- LOGO was developed as an offshoot of LISP as the first instructional language for children. LOGO has become very popular with children, especially those in primary and junior classes.
- ADA was especially developed by CII Honeywell Bull for Department of Defence (DOD), USA, for their real-time applications. ADA is now being adopted as DOD standard for all future Defence

projects. It is a structural language, well suited for general purpose applications in addition to real-time and embedded usage.

APPLICATION SOFTWARE

Application software consists of a vast range of user programs for solving specific problems. There is a thriving cottage industry for supplying application programs for various applications. Application packages fall into two categories: specialized packages oriented toward a specific task or operation, such as payroll or inventory, and generic tools used to develop customized models or personalized solutions to problems.

Design Cycle for Application Software

Application software decides the actual utilization of the computer system. A new branch of computer science called Software Engineering has evolved during the last decade to ensure efficient design and development of software. Figure 3.4 represents the overall flow of events during the software life cycle.

The software life cycle establishes the chronology of software engineering events. The life cycle begins when software is defined as an element of a computer-based system. The cycle consists of three phases.

Planning phase. It concentrates on software project planning and requirement analysis/specification. Project scope is defined and estimates for budget and schedule are developed. Scope is further expanded into a detailed written specification of the requirements.

Development phase. Requirements must be transferred to a form which can be executed by a computer. This phase does so by applying design methods to generate a software, which can then be coded into the programming language resulting in a computer program. Finally, various tests are applied to assure quality and compliance with software requirements.

Maintenance phase. It begins when software becomes operational. This phase consists of two major functions that occur throughout the life of the software.

(i) *Software supervision.* It is the on-going management of the computer programs. It involves control and protection of software.

(ii) *Maintenance.* It is a set of activities that result in modifications to the computer program.

During the last decade the hardware costs have dropped considerably. The software is comparatively more expensive. At present the cost of software is nearly 80 per cent of the total system cost. Thus, there is a pressing need to ensure proper application software for different areas.

Software Tools

A new range of Computer-Aided Software Engineering (CASE) software called *software tools* have appeared in computer world, to assist the sofware designer to implement software engineering solutions.

- Use of structured system analysis and design techniques to control complexity in software design.

- Use of modelling/prototyping techniques to enable the designer to explore the nature of the system in the development cycle.
- Use of design dictionaries/repositories to control the chain reaction of changes during development/operation of complex software.

Some of the common CASE tools available in the Indian market are EXCELERATOR, VULCAN and TURBO ANALYST. Though primarily designed to work on mainframe computers for major software projects, these tools are also available under PC environment.

Database Management System

Database Management System (DBMS) is a typical example of generic application packages provided on most mainframes and minicomputers. *Database* is described as a collection of files used by an organization for storing inter-related data for use in different applications. DBMS is a collection of software for using the database. The software assists in creation, retrieval and modification of the information. There are three basic approaches for database design—hierarchical, network and relational. Relational DBMS packages (wherein data can be retrieved from the database by naming any arbitrary relationship between the data elements and the database) are becoming more popular nowadays,

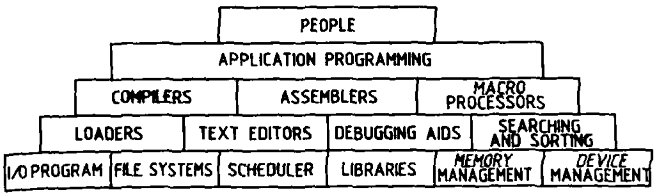

Fig. 3.1 Building blocks of system programming

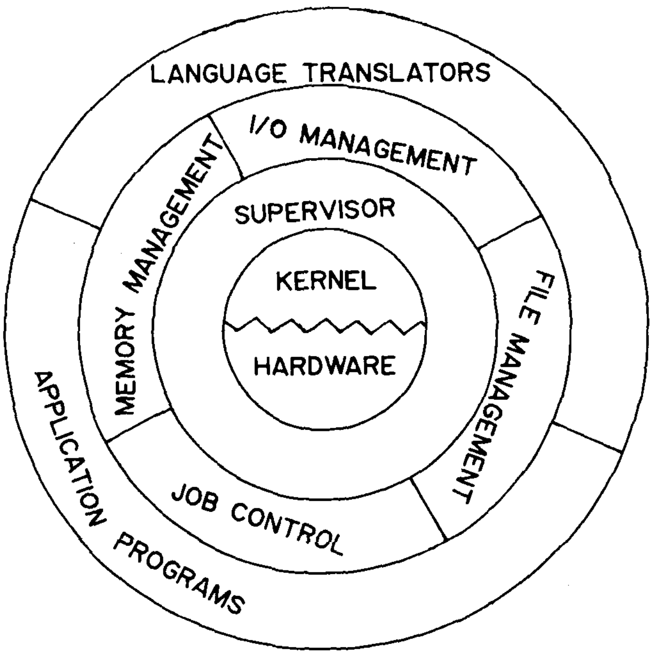

Fig. 3.2 Operating system shells

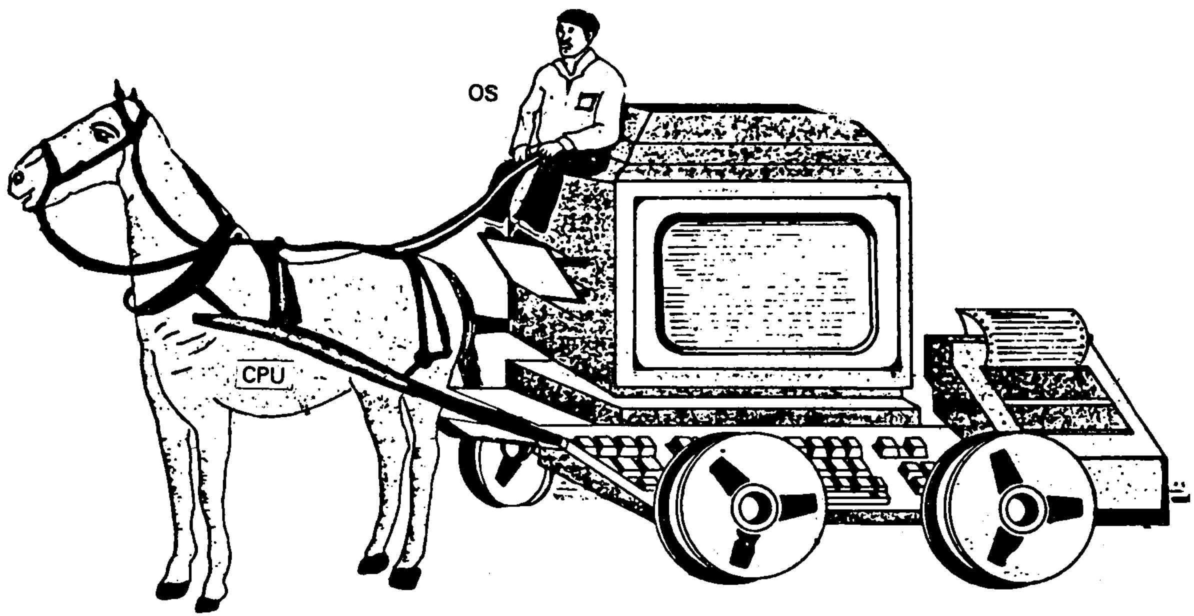

Fig. 3.3 The OS as monitor of computer system

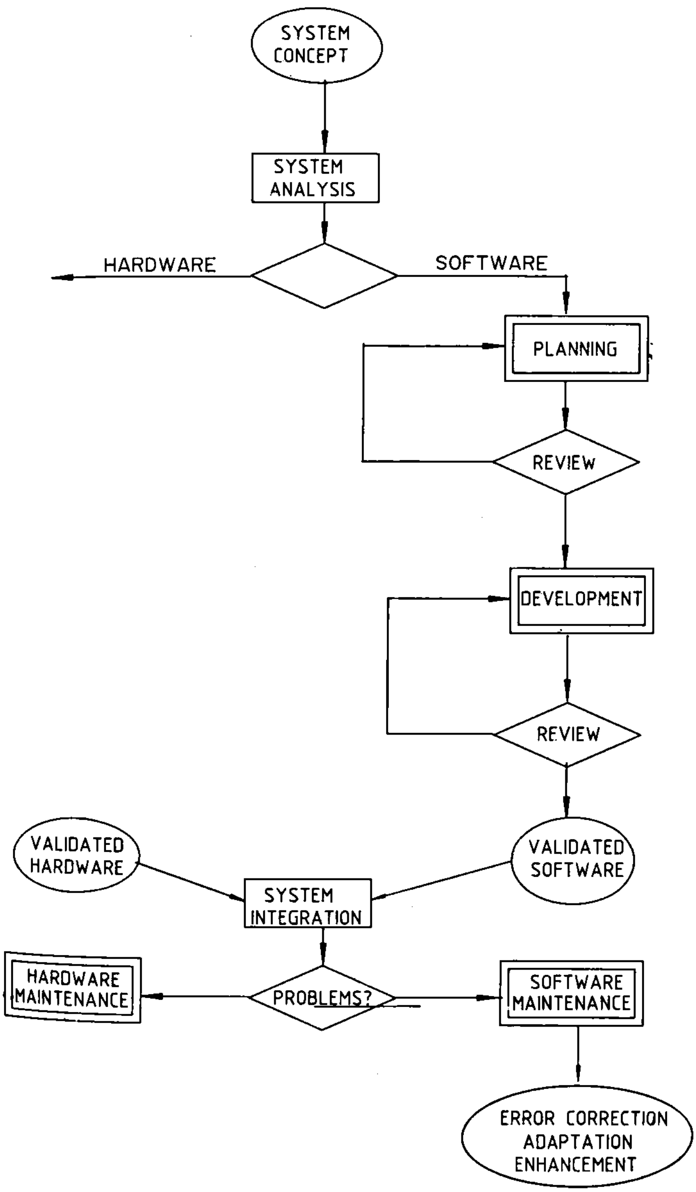

Fig. 3.4 Sequence of events in software lifecycle

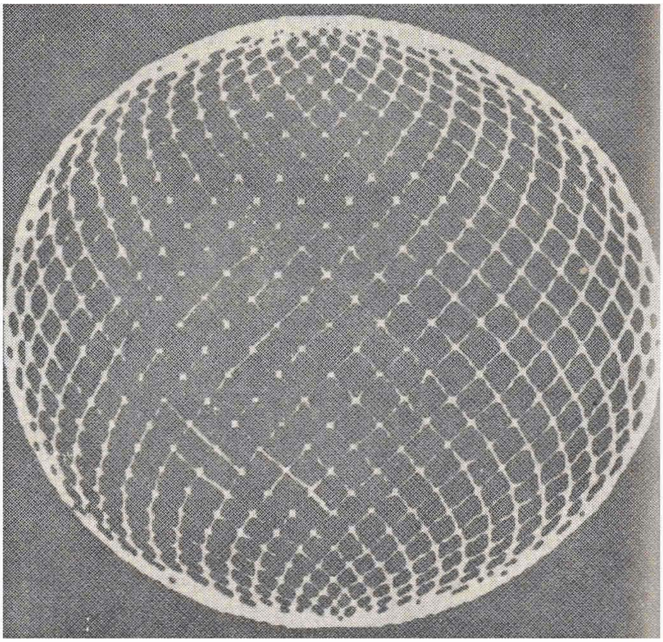

Fig. 3.5 Multiple ellipse created with BASIC program

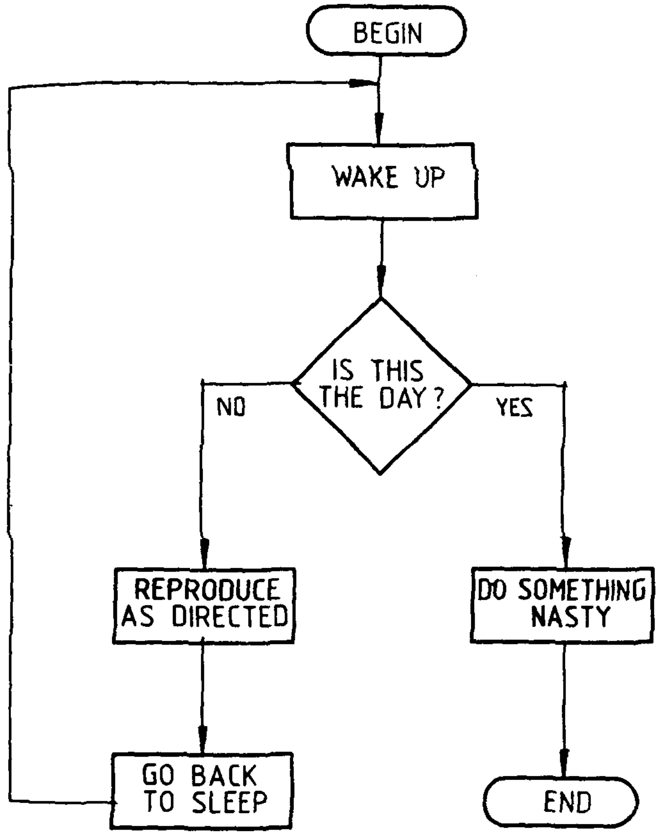

Fig. 3.6 Working mechanism of a simple virus

because of their simple concept. A powerful query language is provided to non-programmers for accessing the database. An integrated database implementation provides an organisation a means for effective control of data and reduces redundancy and inconsistency. Some of common DBMS packages available in Indian market are ORACLE, SYBASE, INGRESS, UNIFY and C-SQL. Some of these packages have also started providing 4GL (Fourth Generation Language) features like forms manager and relational report writers.

PC Software

The availability of PCs for less than Rs. 11,000 from ET&T has put at the disposal of individuals the same basic computing power as the mainframe computer of 1960s or the minicomputers of 1970s. PCs have brought in a 'computer revolution' in almost all areas of computer applications, including Defence. Some PCs may bring supercomputer power on a desktop. For non-professional computer users, BASIC provides a simple and powerful language for experimenting with PCs. Figure 3.5 shows a simple graphic generated with the following BASIC program.

```
10 KEY OFF:CLS
20 SCREEN 2
30 SIZE=150
40 ASPECT=2.2
50 PI=3,1417
60 PSET (400,100+SIZE/ASPECT)
70 FOR A=0 TO 20*PI STEP .05
80 X=SIZE*SIN(A)*COS(A/40)
```

```
90 Y=SIZE*COS(A)/ASPECT
100 LINE -(400+X,100+Y)
110 NEXT
120 PSET (400+SIZE,100)
130 FOR A=0 TO 20*PI STEP .05
140 X=SIZE*SIN(A)*COS(A/40)/ASPECT
150 Y=SIZE*COS(A)
160 LINE -(400+Y,100+X)
170 NEXT
180 END
```

Word processing. With the emergence of efficient application software, the PC has ceased to be a mere entertainment tool for video games. PCs are extensively being used for business and scientific applications. Word processing still continues to be the most common application. 'Wordstar' is one of the earliest application packages and is still quite popular with all PC users. It is used by individuals for a variety of jobs like writing short memos, preparing book-length manuscripts and compiling mailing list of hundreds of addresses. Efficient editing and manipulation features are very useful and save time and effort. 'Word Perfect is another package, which is also becoming popular. Spelling checkers are also being made available with most of the word processing packages.

Electronic Spreadsheet or Worksheet programs are used to analyse data. These are used as a large sheet of paper ruled off into columns and rows to develop a budget or analyse the effects of changes in interest rates or prices, on a firm's profitability. 'Lotus 1-2-3' is also a standard package on all PCs. Many industry experts cite worksheet programs as the most important reason why PCs have become popular. The latest version of Lotus 1-2-3 from Microsoft offers a 2048 rows by 356 columns spreadsheet, with more than 50 mathematical, financial and statistical functions.

dBASE IV is the latest popular version of DBMS package developed by Ashton-Tate for PCs. This software package makes use of all the basic concepts of DBMS and in addition offers many advanced features, including a query interface—SQL—on the lines of relational DBMS.

Auto CAD is a two-dimensional computer-aided drafting and design system suitable for a wide variety of applications, including architectural/landscape drawing, drafting for mechanical, electrical, chemical, structural and civil engineering.

PC Virus

In late 1980s, the whole world was shocked by a big threat of computer viruses, primarily an offshoot of the PC culture. A computer virus can be defined as a malicious software, which replicates itself like its biological counterpart. It is a program mostly written in assembly language containing instructions for self-replication and infection of other programs or data. A variety of interesting viruses like 'Trojan Horse', 'Worm', 'Happy Birthday Joshi' 'Marijuana' 'Stone' and 'Logic Bomb', have been reported in India. The working mechanism of a simple virus is shown in Fig 3.6. Depending on the target site for hiding, there are boot sector viruses, file viruses and partition viruses. A number of diagnostic programs like

Integrity Checker, Interrupt Monitor, Memory Scanner and Disk Scanner are now available. So also anti-virus vaccines, the software to kill (remove) the virus, have flooded the market. In fact, computer virus was even reported during Gulf war. It is claimed that the French-made Exocet missiles missed their targets because the software for launching and controlling them were infected by computer virus. It was also reported that due to the presence of 'Marijuana Stoned' virus, a large volume of data pertaining to Iraqi prisoners of war was destroyed, when some PCs in Saudi Arabia got infected. One of the main sources of virus is use of pirated software, which is done by exchanging cheap floppies.

The range of software is unlimited and provides enormous power to computer specialists and non professionals in solving their problems. The power of a computer system is determined more by the quality of its software than its hardware. It is the software which makes the hardware work as a computer system.

4

Defence Applications of Computers

GENERAL

Initially the high computation capability of computers was utilized in major weapon systems and Electronic Warfare (EW). With the advent of microprocessors, each and every area of military equipment and operations has been pervaded by computers. The need for accurate and timely information is vital for Defence. Computers with their high speed and unlimited storage are revolutionizing the concept of warfare. It is believed that in the years to come, major battles will be fought in laboratories, rather than in the battlefields. In fact the Gulf war (covered in Chapter 5) has made a beginning in high technology warfare using computers and electronics.

MILITARY WEAPON APPLICATIONS

Rugged Computers

Microprocessors are replacing most of the instrumentation of artillery guns. The tactical boards are being replaced by video display boards displaying real-time battle situation. The entire computation for setting of the guns for azimuth and elevation depending on environmental conditions and charge used, is being entrusted to field-grade ruggedized computers. Figure 4.1 shows the R/630 model of Digital Micro Vax II ruggedized computer, meeting military specifications for field use.

Tracked Vehicles

In Armoured Fighting Vehicles (AFV), the battlistic computers are relieving the tank commanders from the task of consulting complex tables and then making judgement, by providing accurate information for engaging the enemy tanks and tactical targets. A ruggedized PC with efficient software can provide the tank crew valuable information on terrain, obstacles, routes and state of the vehicle. Integrating it with reliable communication of the squadron would increase manifold the efficiency of the amoured fighting column.

Night Vision

Microprocessor-controlled night vision systems are increasingly being used in basic infantry and anti-tank weapons for higher accuracy during nights. Mobile computer systems are being employed for a wide range of communications network and general purpose computing need at forward field locations. Figure 4.2 shows one such high performance mobile computer system, which is easy to operate, is transportable, operates on vehicle power system and is designed to military specifications.

Fly-by-Wire Fighters

Complex computer systems are essentially required for high performance fighter aircraft, as time is of essence in all air battles. Extensive use of microprocessor-based cockpit instrumentation is made to give accurate and timely information to the fighter pilot. Separate on-board computer systems to assist in navigation in adverse environmental and tactical situations are also provided. Figure 4.3 shows the US Navy's all-weather attack aircraft A-6F cockpit instrumentation, which was redesigned using computer technology. Computerized fly-by-wire flight control has been introduced on most of the high-speed aircraft for better response. The fly-by-wire concept was developed for aircraft in which the traditional level of natural stability has been exchanged for a high level of instability, thereby benefiting performance, weight and cost. F-16 and F-18 of the US Air Force are both marginally stable aircraft, but have fly-by-wire systems for safe agility and pilot protection at high angle of attack.

Advanced Tactical Aircraft

Almost all tactical aircraft being used by the air forces of different countries make extensive use of computers for various on-board applications. The ATF (Advanced Tactical Fighter) being designed for the US Air Force will be even more dependent on embedded computers than was its ancestor, the F-16.

ATF has the distinction of being the first weapon system to be completely coded in ADA from engine control boxes to tactical computations. Aircraft are also using microprocessors for airborne instrumentation for transmitting flight data for processing and displays. Figure 4.4 is a typical example of an airborne instrumentation subsystem which is mostly based on the latest microprocessors.

Missiles

In all types of strategic and tactical missile systems, extensive use of mini and microcomputers is made to improve their accuracy. In surface-to-surface ballistic and cruise missiles, a very powerful on-board processor capable of image processing is used to navigate the missiles to the target. In air-to-surface missiles, microprocessors have extensively been used to process on-board parameters to correct their course. In suface-to-air missiles, both in the ground and the on-board systems powerful computers are utilized to ensure high probability of hit. Even in India's Integrated Guided Missile Development Programme (IGMDP), extensive use of computer technology has been made by DRDO. The successful launch of *Agni* is attributed to the use of computers in a big way. In the words of Dr APJ Abdul Kalam, Chairman, Programme Management Board of IGMDP, 'There were two major ways of checking out *Agni*. One was the Hardware In-Loop Simulation (HILS) technique and the second the multi-mode automatic check-out. At various stages, until the missile actually reached the launch site, we did various tests and all deviations

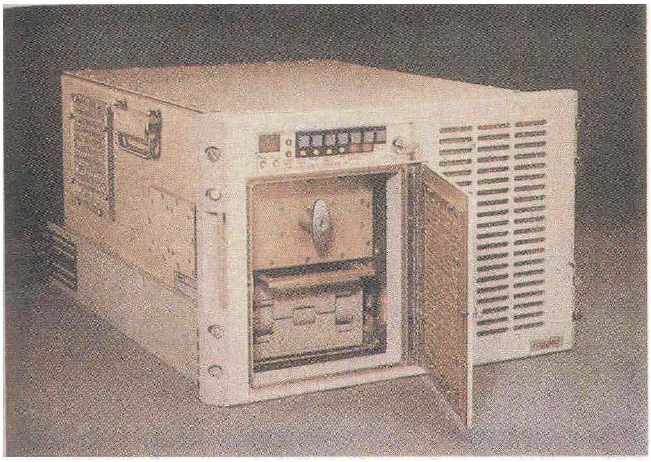

Fig. 4.1 Ruggedized R/630 model of Digital Microvax II

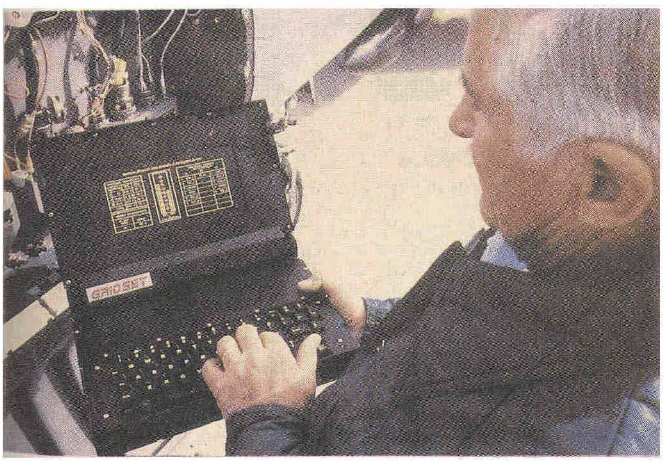

Fig. 4.2 High performance mobile computer system

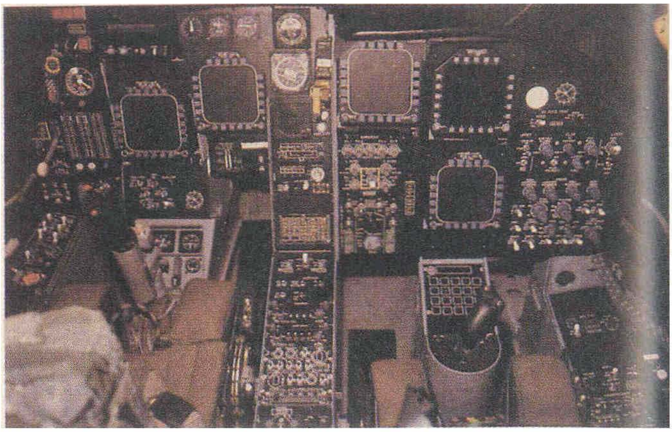

Fig. 4.3 Cockpit instrumentation of A-6F aircraft being redesigned using computer technology

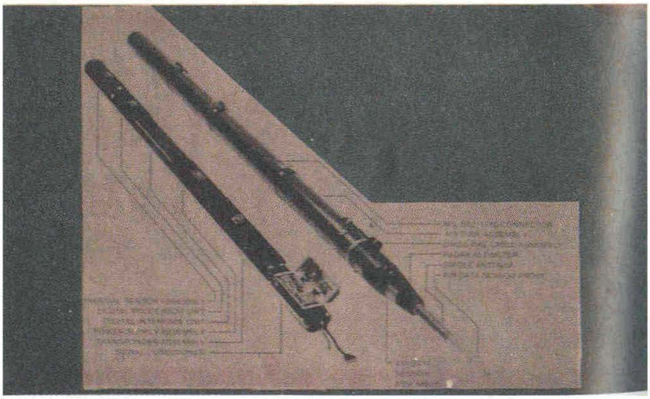

Fig. 4.4 Airborne instrumentation subsystem controlled by Intel *8086 microprocessor*

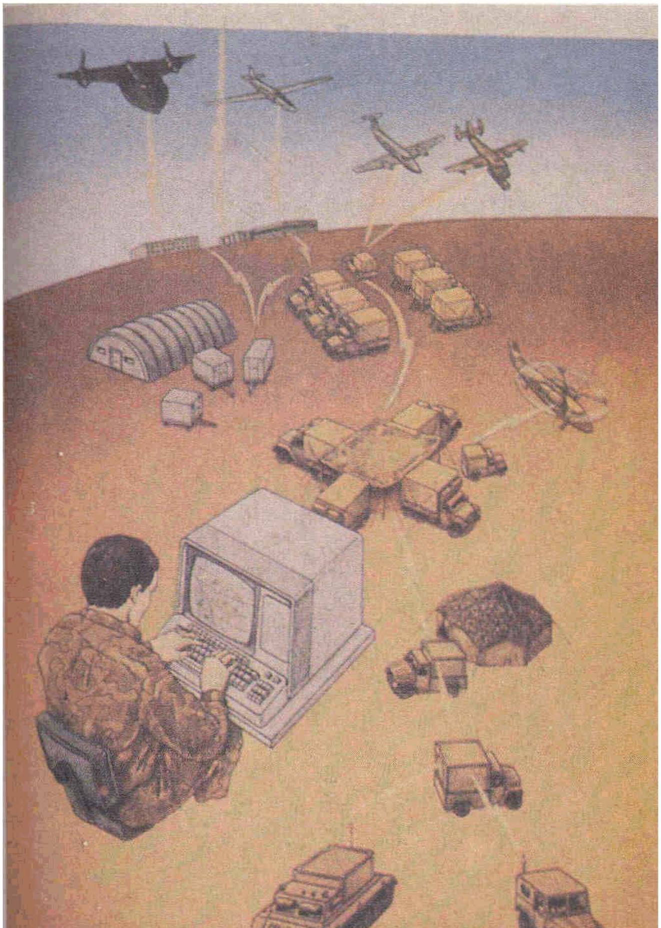

Fig. 4.5 Artist's view of data integration for C^{3}I system

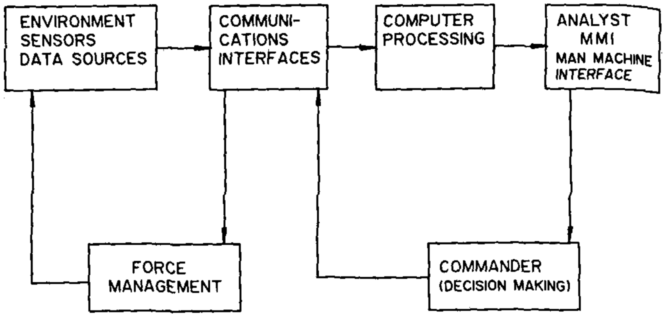

Fig. 4.6 C^3I scenario

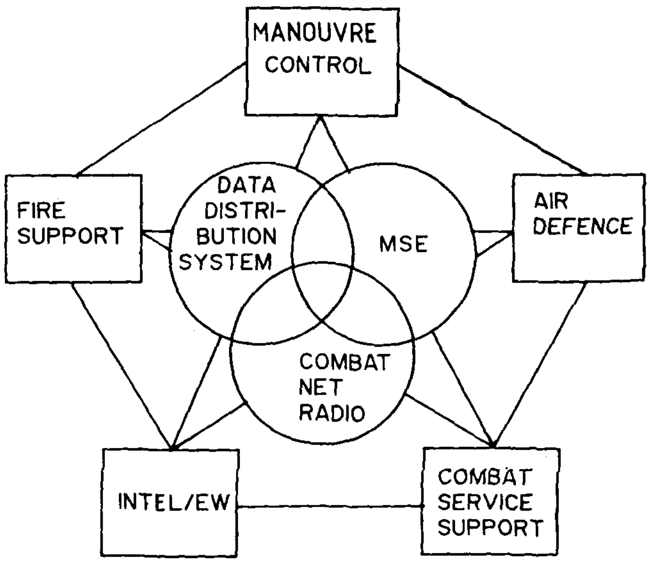

Fig. 4.7 Block diagram of Army command and control system

Fig. 4.8 Seventh US Army's AN/UYO 30 tactical computer system

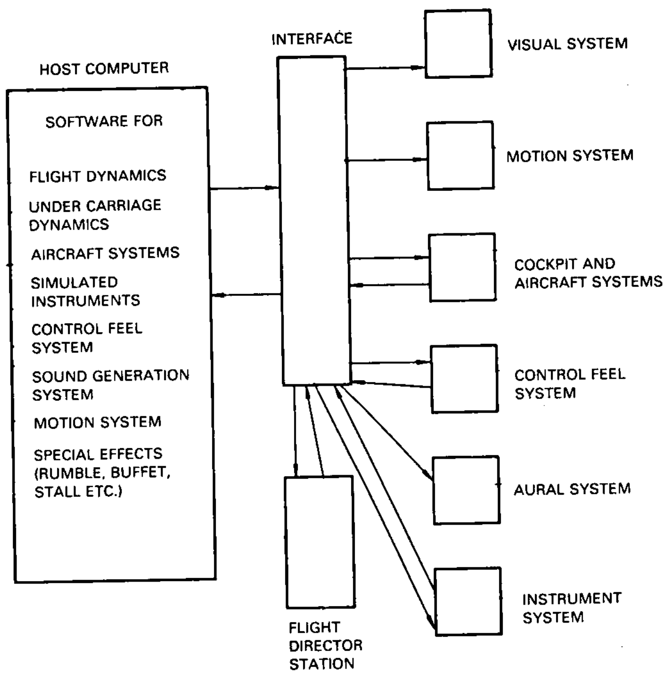

Fig. 4.9 Typical flight simulation facility

were recorded and it was put on hold, unless it met the required parameters'. DRDO had last year successfully test-fired *Prithvi* surface-to-surface missile having a range of 250 km. Both *Agni* and *Prithvi* use strap-down inertial navigation in closed loop guidance system, with on-board computers for guiding the missile in its flight.

The use of strap-down inertial guidance system is claimed as a pioneering effort by DRDO against the conventional platform guidance system, using stabilization by gimbals. In *Agni* and *Prithvi* missiles, the gyros and accelerometers are strapped-on and they give their output to the computers, which instantly convert it into inertial measurements. By extensive use of computer technology both the missiles have been able to achieve trajectories very close to the predicted and simulated paths. The other projects under IGMDP, i.e., *Trishul, Akash* and *Nag* are utilizing computer systems for design and testing. *Nag*, the third generation 'fire-and-forget' anti-tank missile, uses computer-based image processing for acquiring the target and then 'homes on' to it.

COMMAND, CONTROL, COMMUNICATION AND INTELLIGENCE SYSTEMS

Command, control, communication and intelligence systems (C^3I) provide accurate information to the commanders at various levels to exercise effective command and control using reliable communications. In the present day, the degree of integration of command and control systems in weapons with the communication techniques is increasing. In a broader sense C^3I embraces the entire range of activities consisting of such diverse elements as wireless, satellites, aircraft sensors and telecommunication networks. Figure 4.5 depicts an artist's view of integrated data from multiple sources and sensors forming the backbone of a C^3I system. The basic elements of C^3I are surveillance, communication, computation, decision making and action.

Surveillance

The first important step in the functioning of a C^3I system is gathering information with respect to the enemy's position, resources and capabilities. This is obtained by satellites, radars, sonars, EW equipment installed on land, in ships and in aircraft or in space. In each of these systems, computer technology is playing a major role by reducing the time spent in collecting accurate information.

Communication

Communications form an integral part of the C^3I system. The information gathered in surveillance is transmitted through communication media to locations where such information could be processed and analysed. The decisions based on such analysis are communicated to the theatres of action. A variety of communication links such as satellite links are employed for this purpose. Extensive use of computer-based data switching networks is being made to improve the reliability and security of the communications.

Computer Data Processing and Management

Computers are being increasingly employed in analysing the information and processing the raw data to make it useful for making decisions. Because of their enormous storage and fast speed, computers have become indispensible in the area of battle management.

Decision Making

At various levels, decisions are required to be made to deploy the available resources, including the manpower in the most optimum way to meet the threat effectively. To assist in this decision making, computers are being utilized at all stages. Figure 4.6 depicts a C^3I scenario leading to optimal decision making with a feedback loop.

Action

The information on action to be taken at various command levels and also the information with regard to the actual actions taken should flow in both the directions. Accomplishment of the assigned tasks in full and proper manner constitutes the main goal of a C^3I system. Everything in C^3I is geared to make the 'action' element the most successful one.

Figure 4.7 depicts a typical army command and control system forming part of a C^3I system. It consists of all the communications and automatic data processing hardware used by fire support, air defence, combat service and EW system.

The backbone of the system is the Manoeuvre Control System (MCS) using integrated tactical computers for decision making. Figure 4.8 shows a picture of US Army's AN/UYQ 30 tactical computer system.

SIMULATION AND WARGAMING

Fast and powerful computer systems and efficient simulation software make it possible to configure and develop real-time man-in-loop simulation system. It provides cost-effective and time-saving support towards design, development and training programs in respect of complex military systems. Simulation is an extremely useful technique, which enables better understanding of dynamic behaviour of complicated physical systems through mathematical modelling. The real-time ground-based simulator systems have proved efficient in providing ab initio training to human operators, without putting them at risk on the real-life system being simulated. This also increases the operational life of the sophisticated and expensive modern weapon systems, which otherwise would have to be utilized for training.

R&D Simulator

A versatile real-time simulation facility provides research and development support towards the study of configuration and their modification with the objective of assessing qualities of the present and future generations of weapon systems. A typical flight simulation facility shown in Fig 4.9 will consist of the following subsystems: (i) host computer; (ii) 6 DOF motion cue generation system; (iii) CCTV based visual cue generation system; (iv) simulated flight instrumentation; (v) control feel cue generation system; (vi) aural cue generation system; and (vii) cockpit system.

The system configuration and the software module not only make the simulation of a flight mission highly realistic, but also make it possible for the simulation engineer to interact usefully with the aircraft designers to study every possible aspect of the configuration. A real-time interface system provides the requisite communication either way, where necessary, between the computer and the respective hardware. The hardware and software features are designed to generate dynamic displays, which create highly realistic environment.

Air Combat Simulator

This facility provides for assessment of the combat capabilities of a combat weapon system. In case of aircraft, the facility helps in evaluation of capabilities of proposed configuration of futuristic combat aircraft and also to study the capability of new generation weapon systems, covering both dogfight and beyond visual range weapon release. For training purposes, special simulators are used for each of the major weapon systems. The main objective of the hardware and software is to provide highly realistic environment for trainees to gain full confidence before using the actual weapon system. Complex simulators for training on missiles and tanks use computer system interfaces for assessment of trainees.

Wargaming

Another major area where computer systems have been effectively utilized is wargaming. A simulation of battlefield situation is provided to different levels of commanders to test their professional skill and decision-making capabilities. A computer system provides flexibility of use of the visual displays for different operations of war. Highly complex situations can be simulated with the help of powerful computers now available. The model builder normally starts with a simple model and gradually refines it, after review by the experts. Expert system technologies, such as production rule system, allows the designer to acquire and represent the collection of heuristic rules in computer-compatible form. The system can also include master control program, that determines the order in which the rules could be applied against the monitored system performance to arrive at appropriate system control.

A number of dynamic simulation probabilistic models for Tank vs Tank battle have been developed and are being utilized to determine the effectiveness of battle tactics. Some efforts are also being made to develop combat simulation using expert system techniques to make these more useful.

CAD/CAM/CAE

During the last two decades, the meaning of the acronym 'CAD' has changed several times. Initially

CAD was almost synonymous with finite element structural analysis. Later the emphasis shifted to Computer-Aided Drafting. With the advent of three-dimensional (3D) capabilities and CNC (Computer Numerical Control) machines, other areas such as Computer-Aided Manufacture (CAM), Computer-Aided Testing (CAT), Computer-Aided work Planning (CAP) and computer-aided maintenance came into limelight. Computer-Aided Engineering (CAE) is now used to summarize all computer aids in design and manufacture, while the term CAD has a wider meaning including computer-aided analysis, drafting, design and documentation.

Although military weapons and equipment can be subdivided into specialist systems such as missiles, tanks, radars or bridges; aeronautics and mechanical engineering form an essential part of all these systems. With the possibility of storing 3D geometric models in the computer, the CAD/CAM technology is having a major impact on the design and development of all major subsystems. The time delay in bringing out later versions of weapon systems has been telescoped by using these revolutionary techniques. Even in the design of electronic circuitry CAD/CAM is providing optimized logic simulation and PCB layout.

Advantages

CAD/CAM generally aims at higher productivity in all areas of Defence applications by providing the following.

- Optimized design which means fewer modifications
- Accurate modelling complete with clear colour shaded pictures, which are nearer to the net shapes
- Accurate and fast analysis
- Production of accurate drawings through interactive graphics and major time saving in modification
- Very fast way of designing toolings
- Interfacing to NC/CNC machines through visual display of tool path and automatic NC tape preparation
- Highly interactive and prompting nature of the system
- Integrated database

MIS APPLICATIONS IN DEFENCE

Pay and Allowances

Probably the first Management Information System (MIS) application of computers was in the area of pay and allowances. Pay and allowances of Service officers, as well as combatants have been computerized and are functioning satisfactorily. By and large, the working level has been convinced about their utility. All such software packages have to be maintained and are regularly modified based on various revisions of pay structures and emoluments.

Inventory System

A large number of major depots/establishments holding high volume of inventory have been utilizing computerized inventory systems for effective control of inventory. Regular ABC analysis, as well as provisioning actions for critical inventory items are being taken by the computerized inventory systems. However, there is a need to integrate various inventory systems held in different depots to ensure overall control of the inventories.

An effective control of inventory would result in taking preventive measures for dead stock and time expired items.

Weapon/Equipment Status

Weapon/equipment status is required to be monitored at regular intervals, especially by the Defence Services to find out their readiness for war. Though some action towards computerization has been taken, most of such information is still being handled manually primarily because of its classified nature. It is felt that equipment weapon status can be computerized to give more accurate record, so that timely action can be taken for procurement/discardment of vital equipment. Present computer technology provides a certain degree of secrecy and security for the database, so that the same is not vulnerable.

Production Planning and Control (PPC)

A large number of workshops in Defence, including DRDO, have sophisticated machinery for undertaking design/production of various systems/sub-assemblies. Most of these machines are being handled by manual job scheduling, thereby resulting in their non-optimal utilization. A number of efforts have been made to develop efficient computerized production planning and control systems, incorporating job or machine scheduling, which could be used by major workshops/production units in Defence.

Project Management

Project management of various timebound tasks by the Services, as well as Defence Public Sector Undertakings and DRDO, needs an efficient management system to monitor the various activities for timely completion of the projects. Unfortunately, very few computer applications in this area have been reported. Attempts are being made to develop a computerized programme management system utilising DBMS approach for monitoring and control of the vital projects. With increase in complexity and cost or time of the projects, we can ill-afford the delay in implementation of an efficient computerized system for project management.

Maintenance/Diagnostics System

For battle-worthiness of weapon systems or equipment, there is need for regular periodic maintenance by specialist agencies. Efficient computer-based diagnostic systems can find effective use for the management, in reducing Mean Time ToRepair (MTTR). Very little effort has been reported in this area also.

Personnel Management

With the type of tenure rotations of the Defence Services, the personnel management system becomes very important to provide job satisfaction, as well as career prospects to all officers and staff working in Defence Services. Even in DRDO and other Defence establishments, the need to provide suitable manpower for different jobs needs careful planning and implementation. An efficient personnel management system using computers can help in meeting some of the important requirements of the management.

Thus computer systems have major applications in almost all areas of Defence. Army, Navy and Air Force are already using a number of weapon systems employing embedded computers. Mainframe systems are also being used as central facilities.

5

Information Technology in High-tech War

GENERAL

Information is a vital resource in any decision-making process, especially when time is limited. The jumbled data available cannot be used unless it is quickly presented in a meaningful form for commanders to take decisions. Information Technology is catch-all term used to describe products and services created by rapid changes in computer and communication technologies and their fusing together (or convergence). Just as hydrogen mixed in suitable proportion with oxygen creates water, so also computer mixed with communication becomes information technology. IT is the new science of collecting, storing, processing and transmitting the information electronically. It is the life blood for all activities, and is growing in importance, particularly in Defence. The convergence of computers and telecommunication technologies has resulted in the emergence of a new complex term, Informatics, encompassing scientific, technological and engineering disciplines and management techniques, which make it possible to deal with data and information in a more systematic manner. Informatics implies the design, development, use and maintenance of the system of information processing, including hardware, software, communication links and their human interfaces.

The advances in science and technology have had their impact on warfare right from ancient times. In fact, the need for more efficient weapon systems has been the main motivating force for development of technologies, ever since. Nobel demonstrated gunpowder. Both the World Wars had contributed in bringing to forefront new areas of science and technologies. Computer itself is an outcome of one such requirement. Since the advent of computer, the science of warfare has undergone major upheavals. Fortunately, there has been no World War III yet; otherwise capabilities exist with both the World powers to annihilate the entire population of all the five continents. There have been a number of minor conflicts like Arab-Israeli war, Korean war, Vietnam war, Falkland war, Indo-Pak war and Iraq-Iran war. The battlefronts in all these conflicts were still using conventional techniques and weapon systems. Each side tried to use ground, sea and air to its advantage resulting in a large number of casualties on both sides. The open international trade made it possible for any nation to build its own arsenal of sophisticated conventional weapon systems. But the recent Gulf war between Allied forces and Iraq was totally a new type of high-tech war. The best of the high technology was used by the Allied troops against conventional weapons of well-established Iraqi forces. This high technology was primarily based on computers and communication and the Gulf war was a true high-tech war. The Gulf war disproved many a canon of wars like, 'numerical superiority'; 'air war alone cannot win a war', 'surprise is essential' and 'Generals always refight the last war'. It also proved that high technology has come to stay as the most potent weapon in all future wars. Let us examine its salient features including its impact on future warfare.

HIGH TECHNOLOGY

Defence forces have always adopted new technologies—after ensuring that new technology offered a quantum improvement in battle-effectiveness of their weapons. However, no new technology can find its use in weapon systems till it is well proven and tested to meet stringent military specifications. The crucial role of the electronic systems and subsystems in the Gulf war in all types of weapons, made it a real high technology war. History may call this war as 'war of the chip' The chip ruled the waves of the Gulf for decision-making in Saddam's command post, Schwarzkopf's headquarters, the Pentagon or the White House or in combat zone on land, at sea or in the air. The chips worked for surveillance, acquisition, targeting or damage assessment; for planning operations, coordination among Allies or in exercising command and control over forces, both strategic and tactical.

Surveillance and Reconnaissance

To ensure availability of accurate information at all levels for taking correct decisions, an efficient surveillance and reconnaissance technology was established in the Gulf before the start of the war. Figure 5.1 shows the main elements used by the Allied forces for providing accurate intelligence about Iraqi defences.

Spy Satellites. There were at least seven different types of 'birds' passing over the Gulf, ranging from the sharp-eyed Key Hole photo-reconnaissance satellites (KH11, resolution 15 cm), to the eavesdropping Magnum which monitored Iraqi radio communication. LACROSSE, the radar reconnaissance satellite, provided vital information about the enemy's installations at night and through the clouds (resolution 0.6-3 m).

AWACS. At any time one of the three Airborne Warning and Control System Boeing aircraft was engaged in mapping the advances of airborne attackers within 700 km and guided friendly fighters to the targets. The ground support complex consisted of three Raytheon MVCF 860 computers to remove clutter and display the map of the area. Capable of processing nine million instructions per second, it could also interpret radar signals, relay map display, assess target status as friend or foe.

Aegies. A computerized ship-based defence system was installed to detect, identify and track a variety of enemy targets—from incoming missiles to surface vessels to submarines. Aegies is a combination of phased array radar, sixteen UYK-7 mainframe computers, twelve Unisys UYK-20 minicomputers, and a whole lot of defensive weapons. The system's command and decision computers processed the readings from the cruiser radar and also signals from similar sensors.

JSTAR. Joint Surveillance Target Attack System for Air Force and Army enabled the two forces to zero in on enemy targets on way to battlefront. The equipment featured a phased array radar, digital communication facilities, a computerized operations and control system with nearly two million lines of program code. The signals from sophisticated phased array radar were processed by a central computer with a large memory. Over a dozen consoles displayed the processed signals in the form of terrain images. The information about the enemy targets could be flashed to the Army's ground stations, which were mobile units fitted with sophisticated computers and communication equipment.

Fighters and Bombers. A wide range of fighters and bomber aircraft like Tornado GRIA, Rockwell OV-10, B-52 belonging to different nations provided the necessary reconnaissance information after their mission, to effectively neutralize Iraqi military targets such as Scud launch sites.

Command, Control, Communication and Intelligence

One of the major tasks accomplished by the Allied forces during 'Operation Desert Shield' was to integrate command, control, communication and intelligence (C^3I) belonging to different nations forming part of the coalition. C^3I is a synthesis of doctrine procedures, organizational structures, hardware and software for meeting the overall objective of defeating the enemy. Figure 5.2 depicts one of the airborne battlefield command control centres deployed in the Gulf war. The centre, based on EC-130 E, had fifteen workstations for updation of computer-generated maps and colour data displays. The information was then passed along to ground headquarters and naval forces. Four optical disks allowed operators to view detailed world-wide map and zoom in from a 2000 sqm presentation to 4 sqm presentation in just two seconds. Some of the key modules are discussed below.

MILSTAR. The existing World-Wide Military Command and Control System (WWMCC) has given way to the satellite-based MILitary Strategic and TActical Relay (MILSTAR) for providing reliable communication system to support US and other multinational forces. It linked Pentagon with the headquarters of the Central Command, the Commander of the Gulf forces and its subordinate headquarters.

NAVSTAR. The NAVigation Satellite Timing And Ranging (NAVSTAR) and Global Positioning Systems (GPS) provided the much-needed fix in location, velocity, and time domain for meeting the need of every unit and platform whether operating below, on or above surface. It had the capability of determining longitude, latitude and altitude to an accuracy of 16 m SEP (Spherical Error Probability), velocity to 0.10 m/s and time within 100 ns.

JTIDS. It is a Time Division Multiple Access (TDMA), fully secure, jam resistant, digital information distribution system, with multiple pathways architecture. All JTIDS terminals allowed users to insert or extract required information. The system's capacity was large enough to support widely distributed platforms and decision centres, aircraft surface ships, submarines and ground units, which may be source of information or its consumer.

Electronic Warfare

Long before the start of air battles on 17 January 1991, the electronic wargame was active in Gulf. The countries surrounding Iraq, particularly Saudi Arabia and Israel, were fully utilizing their sophisticated and sensitive receivers and other passive systems for monitoring the electronic emission from Iraq's communication links, radars, aircraft, tanks and other weapon systems. It was probably the first time in warfare that such sophisticated systems including Remotely Piloted Vehicles (RPV) were used to draw an accurate 'electronic order of battle'. Figure 5.3 shows General Colin Powell showing a drop in radar activities after the start of the air war, thereby proving the effectiveness of Electronic Counter Measures (ECM).

The Iraqi air defence system against which the electronic war was fought had both strategic as well as tactical support provided by equipment from both East and West. The entire range of radar frequencies from 70 MHz to 18 GHz was used. The well-equipped Allied high-altitude aircraft like F-16/F-15 used their LOng Range Oblique Photography (LOROP) and SIGnal INTelligence (SIGINT) missions together with data up to 160 km beyond the border. A typical layout of Electronic War System (EWS-16) on F-16 aircraft is shown in Fig. 5.4. It is a broad coverage (from C to J band), computer-controlled electronic counter measure system which provides state-of-the-art threat warning, power management, radio frequency jamming and chaff/flare dispenser control. F-4G Wild Weasels combat aircraft was specially designed to attract ground-based radars. They fired High-speed Anti-Radar Missile (HARM), locking horns with Iraqi radar signals and destroyed the surface-to-air missile sites.

Night Vision

One of the important factors which played a vital role in the Gulf war was the night vision capabilities of the Allied weapons. The air offensive in Operation Desert Storm relied heavily on aircraft equipped with navigation and attack systems able to penetrate Iraqi airspace at night. Even during the ground battles in Operation Desert Sabre, extensive use of night vision devices was made by all tanks and infantry soldiers. F-15E aircraft were fitted with Low Altitude Navigation and Targets InfraRed Night (LANTIRN) system designed by Martin Marietta. The system mounted under the belly of the aircraft, comprised a navigation pod having wide field Forward Looking Infrared Radar (FLIR) and a terrain following radar. The targeting pod had a laser designator/tracker with narrow field FLIR and automatic target tracker. Each of the pods had its own computer using 2,00,000 lines of source code to help the pilot in accurate engagement of targets at night. Figure 5.5(a) shows LANTIRN fitment on F-15E. The pilot's view of the system FLIR picture on head up display is shown in Fig. 5.5(b).

Surgical Precision

Smart bombs based on precision guidance is one example of the key high technology used during the Gulf war. The US Chief of Staff General Merrill A Mepeak admitted that the conventional bombs missed their target 70 per cent of time whereas Precision Guided Munition (PGM) was highly accurate. A PGM is an air-to-surface weapon with guidance system to steer it on to the target. Some have rocket motor, others guide in. A Laser Guided Bomb (LGB) homes on to a spot of intensive light produced by a laser. The laser illuminating a target can be carried by another fighter/bomber, a smaller control aircraft or by ground troops. Figure 5.6 shows a laser guided bomb fitted on F-117 aircraft and the view of the pilot who attacked the Iraqi Air headquarters. Another version of smart weapon is the Electro Optically Guided Bomb (EOGB), which contains a TV camera or an IR sensor for night attack and a transmitter. After the bomb is released the pilot can take evasive action, while the weapon system operator steers the bomb to the target.

HIGH-TECH WEAPON SYSTEMS

High technology alone cannot win a war, unless it is converted into an effective weapon system for offensive operations or a defensive system to counter the effectiveness of the adversory's weapons arsenal. One key technology which affected every facet of operations Desert Shield, Desert Storm and Desert Sabre during the crucial seven months from 2 August 1990 to 28 February 1991 is electronics. The electronic subsystems formed part of every single activity on the battlefield, some embedded, others supportive, some stand-alone, other commutual, some active and some others passive. The Gulf war proved beyond doubt that 'electronic supremacy' is a critical factor in warfare. Let us briefly see some of the major high technology weapon systems, which decisively brought about Allied victory in the Gulf war. Needless to say computers formed the heart of every high technology weapon system.

Missiles

Gulf war was a true 'missile war', almost like the science fiction film *Star Wars.* The battlefront was brought live in real-time to viewers all over the World by international TV networks like Cable News Network (CNN). The sight of an Iraqi Scud missile being intercepted by a Patriot antiballistic missile (ABM) over Tel Aviv will ever remain in the memory of those who were watching the scene on their TV screens. At times it looked as if one was witnessing a video war game instead of real war. The high technology on missiles has been the result of enormous funding in Strategic Defence Initiative (SDI) programme by the USA to counter Soviet ICBMs (see Chapter 6 for more details). Some of the major high technology missile systems are discussed below.

Cruise Missile. Tomahawk Land Attack cruise Missile (TLAM) has been a real technological marvel and was extensively used against Iraqi strategic targets. Packed with advanced electronics and several different guidance systems, Tomahawks were essentially flying computers capable of sailing through the goalposts of a football field from a range of several hundred kilometres. These could also perform dizzying acrobatics as was witnessed by CNN reporters at Baghdad, when a Tomahawk streaked below their AL Rasheed hotel window and made a pair of swooping 90° turns to avoid hitting the hotel. The secret of Tomahawk's precision flying was a two-step guidance system. On launch from sea, the inertial guidance system using GPS sensors took the missile to coast line. Once over land, the advanced TERrain Contour Matching (TERCOM) system took over and continued guiding the missile on its preprogrammed flight path. Figure 5.7 shows the land attack profile of TLAM. Once in the target area, the Digital Scene Matching

Area Correlation (DSMAC) terminal guidance took over for the final precise targeting based on optics programmed into the system. The four phases of pre-launch and post-launch activities of the Tomahawk missile are depicted in Fig. 5.8. It clearly indicates the extensive use of high technology, in particular computer technology, both in ground and on-board segments, which made this Rs 3 crore missile such a terror in the Gulf war. Tomahawk is about 6 m long, 1470 kg in weight, has low speed (800 km/hr), is propelled by turbofan jet engine and has a maximum range of 1300 km.

Patriot Missile. The real find of high technology in the Gulf war has been the Patriot Anti-Ballistic Missile (ABM) system, though by accident. Patriot was originally designed in 1970s as a surface-to-air missile to counter high-speed aircraft. However, during 1980s, the software-upgraded conversion made it one of the first missiles in the ABM category. This Rs 2 crore missile is guided by a sophisticated phase array radar, consisting of more than 5000 radar antenna elements that can detect and track over 100 targets at a time and follow any given one far more rapidly than the rotating conventional radars. Figure 5.9 depicts the sequence of actions followed by a Patriot battery to detect and destroy enemy missiles and aircraft.

Early warning satellites provided the Gulf batteries a minimum of 90 s warning for incoming Iraqi Scuds. The Patriot missile has a range of 70 km and maximum altitude of 24 km. Its launch weight is 914 kg and it carries high explosive fragmented warhead. The solid propellant burns for 11.5 s, which boosts the missile to 3.7 Mach (Mach is the speed of sound in air) speed. Patriot uses inertial mid-course guidance with semi-active track-via-missile (TVM) terminal homing. The radar illuminates the target for the missile passive seeker. The weapon down-links target data to the battery engagement control station, which then uplinks guidance commands to the missile via the radar.

During the Gulf war, Patriot missiles attained an unbelievable 95 per cent hit against Iraqi Scuds. This was made possible by extensive training of the Patriot crew on Patriot simulator. Figure 5.10 shows a Patriot Operator Tactics Trainer along with graphic consoles, which were used for realistic training. It takes 34 weeks to train a basic console operator for Patriot system. The course for Battalion Commander takes 8-12 weeks. The fantastic success of the first ABM is attributed to excellent combination of high technology and manual skills of the operators.

SLAM. Stand off Land Attack Missiles used for the first time in the Gulf, was another example of using high technology to ensure precision destruction of vital targets, without exposing the pilot to Iraqi defenses. In fact, in the first strike, two SLAMs were used to destroy an Iraqi hydroelectric plant without damaging an adjacent dam. SLAM is a derivative of Harpoon antiship missile, developed by McDonnel Douglas, as a low cost, low risk interim stand-off weapon for the US Navy. SLAM is equipped with a 220 kg warhead (instantaneous or delayed detonation) and has a range of 60 nautical miles. The missile can attack fixed or relocatable land targets and ships in

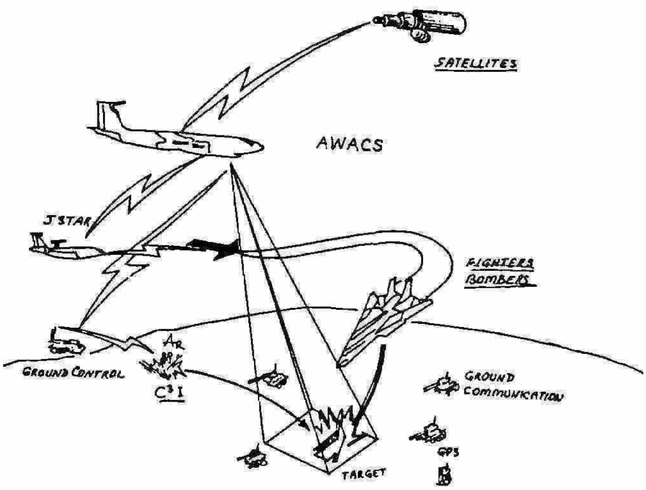

Fig. 5.1 Surveillance and reconnaissance support to Allied forces for neutralizing Iraqi military targets

Fig. 5.2 Airborne battlefield command control centre deployed in EC-130E transport aircraft for C^3I over the Gulf

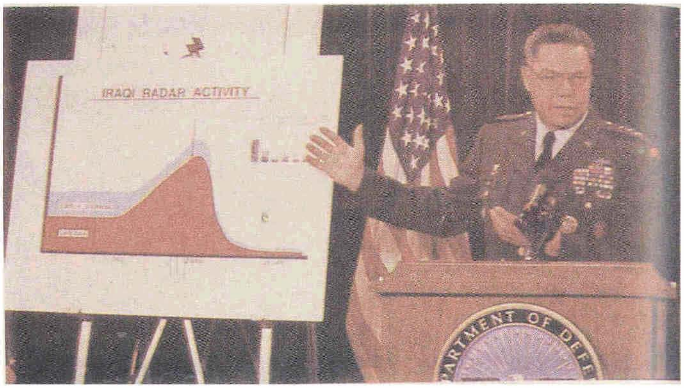

Fig. 5.3 General Colin Powell, Chairman Joint Chief of Staff, USA points to sharp drop in Iraqi radar activities after 17Jan 1991 in a press briefing at Pentagon

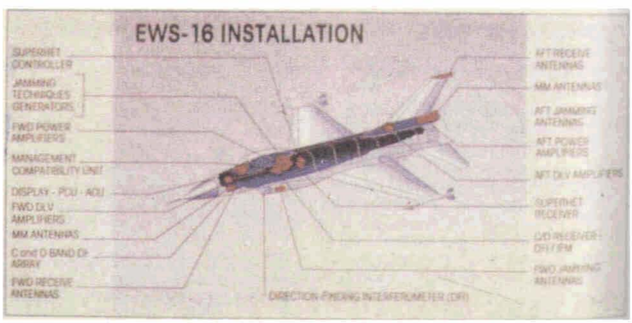

Fig. 5.4 Layout of EWS-16 Electronic Warfare system fitted on F-16 fighters

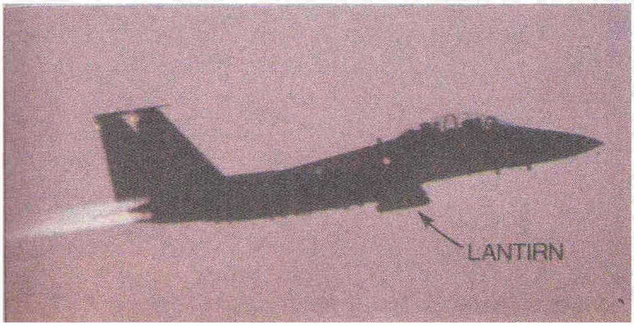

Fig. 5.5(a) LANTIRN night attack system fitted on F-15E

Fig. 5.5(b) View of the pilot's eye on FLIR as displayed in darkness

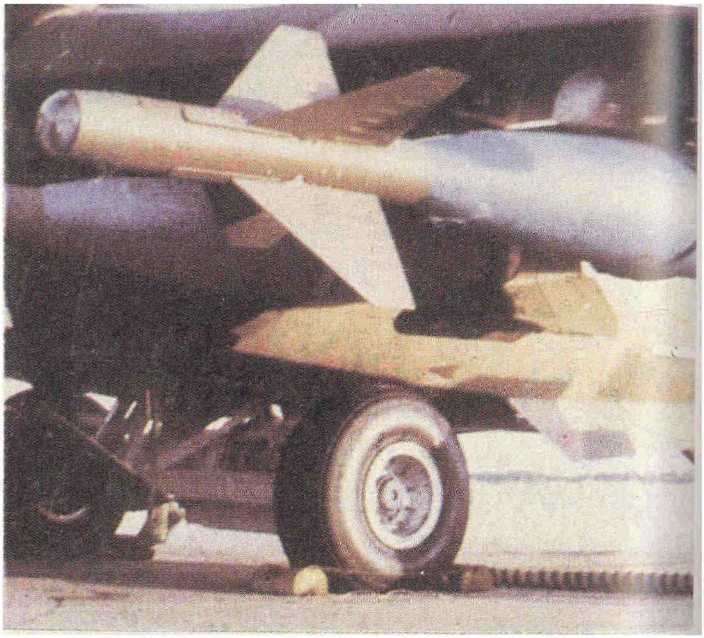

Fig. 5.6(a) A Laser Guided Bomb (LGB) mounted on a F-117 fighter aircraft

Fig. 5.6(b) The view as seen by attacking pilot for guiding LGB

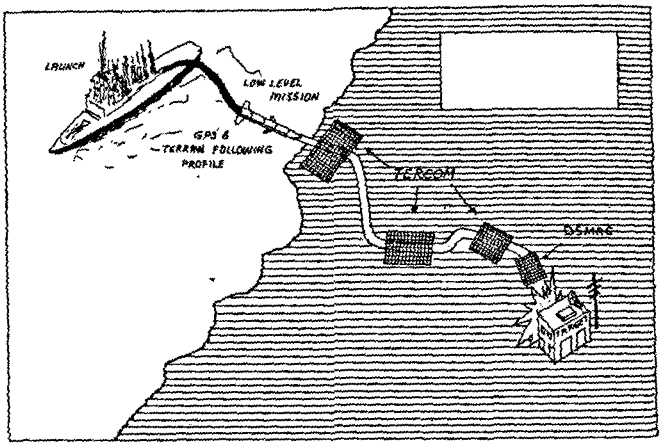

Fig. 5.7 Phases of cruise missile showing high technology navigation and guidance

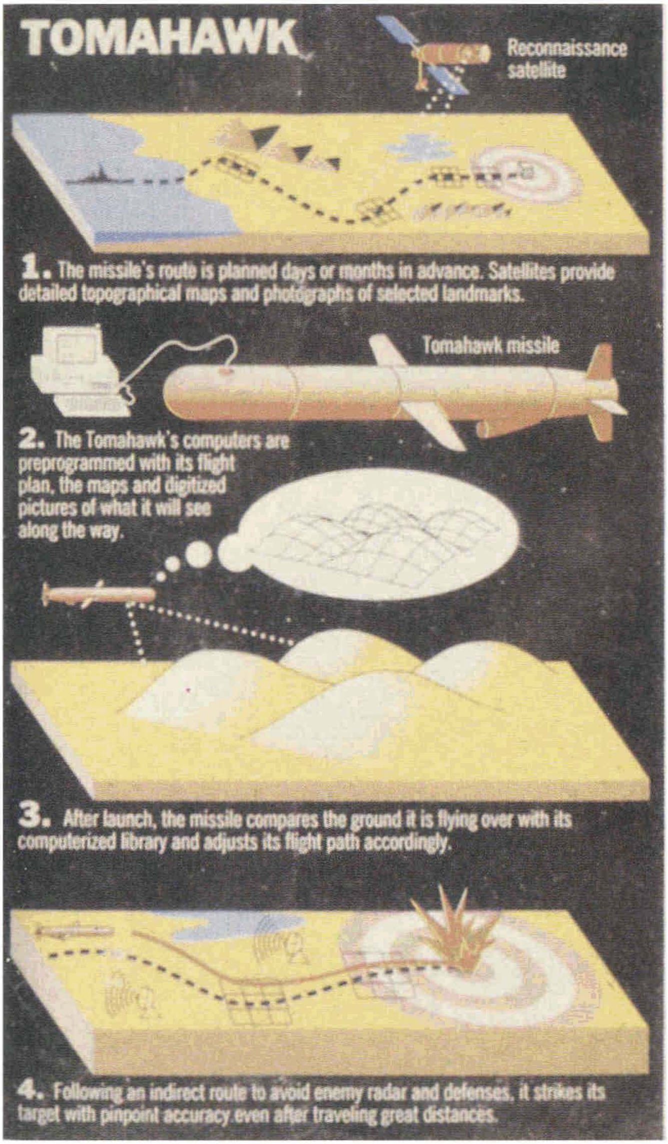

Fig. 5.8(a) Four phases of pre- and post-launch activities of Tomahawk cruise missile

Fig. 5.8(b) Tomahawk cruise missile in flight

Fig. 5.9(a) US Patriot missile, the first antiballistic missile used in Gulf war

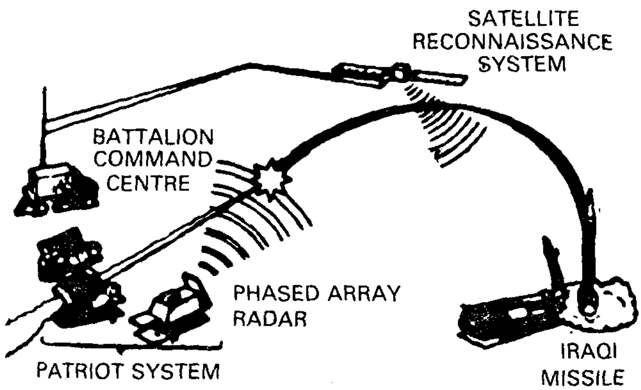

Fig. 5.9(b) Patriot ABM intercept profile

Fig. 5.10(a) Patriot operator tactics trainer

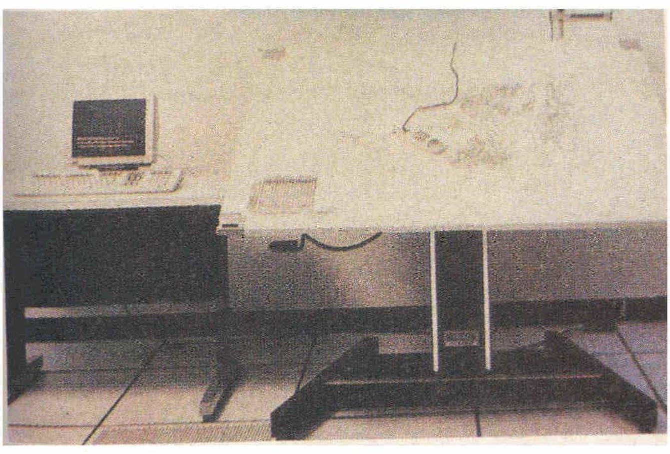

Fig. 5.10(b) Computer and map board of Patriot simulator

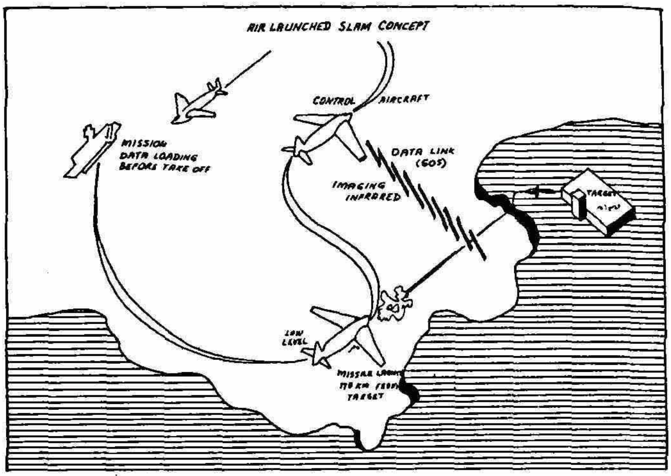

Fig. 5.11 Stand off Load Attack Missile (SLAM) profile sequence of operation

Fig. 5.12 SLAM mounted on allied F-18 fighter aircraft

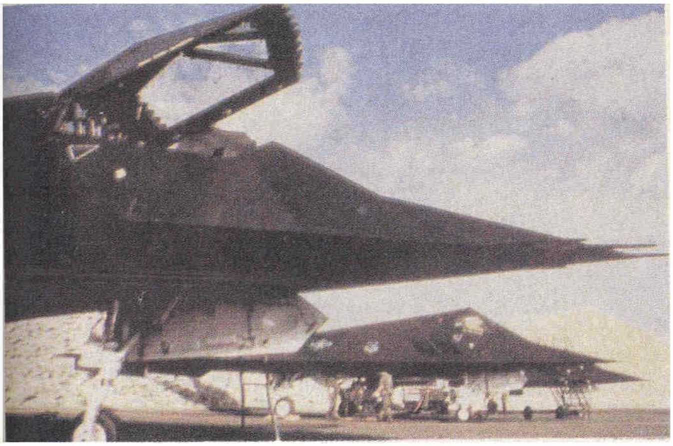

Fig. 5.13 The F-117 stealth fighter having very low radar cross-section

Fig. 5.14 Pioneer, the UAV used in Gulf war for bomb damage assessment and other work

port using preplanned mission data, or it can operate in a target-of-opportunity mode to attack ships at sea. Typically, three preplanned and one target-of-opportunity mission developed at sea is loaded into each missile, and final mission selection is made during captive flight prior to launch.

Figure 5.11 shows the sequence of operation of an air-launched SLAM. The mission plans are generated on a small computer and data loaded into pre-launch data computer, where the information is translated into signals compatible with the weapon system. The reformatted data is then transferred to manportable pre-launch data memory which can hold upto 64 missions stored in groups of four for upto eight hours. SLAM is then mounted on the aircraft (in this case A-6E, see Fig. 12) and mission plans are then downloaded into each missile and retained in EEPROM (Electrically Erasable Programmable Read Only Memory) until purged. Once the attacking aircraft is airborne, it flies to an initiation point so that it can acquire GPS satellite. After SLAM is launched, it navigates towards target using GPS. The missile data link and seeker become active 60 s before the impact. A video image of the target is transmitted back to the control aircraft (in this case A-7E), through the designated data link to select the proper target and to lock on to an aim point.

During the attack on Iraqi power plant the first SLAM made a hole in the external wall and the second SLAM which arrived after two minutes was directed through the same hole, so that it could destroy the actual electric plant inside. The, imaging infrared seeker head employed in SLAM is a modified version of the one used in Maverick air-to-surface missile.

Stealth Fighter

A high performance aircraft designed by Lockheed, using special high technology materials, the F-117A Stealth fighter, also made its debut in Operation Desert Storm. This unique low observable strike aircraft was conceived and designed for covert strikes against small, high-value, well-defended targets. For most angles, the F-117A shown in Fig. 5.13 has the radar cross-section of a small bird or a large insect. Its stealth qualities allow it to penetrate heavy defences with a small, manageable risk of detection and virtually no risk of tracking or interception. An important point of its weapon system is a computer-based mission planner which generates ingress routes, making best use of the F-117A's stealth features against known defences. The Stealth fighter costs Rs 200 crores and has an operational radius of about 500 nautical miles. The low visibility Stealth fighter led the first night attack on Baghdad on 17 January 1991 and achieved an element of surprise. George Bernard Shaw, CNN reporter, observed that the city was not blacked out nor was it put under air alert, when the first air raids took place.

Unmanned Air Vehicle (UAV)

Another important high-tech system tried out during the Gulf war was the Unmanned Air Vehicle (UAV). It is a short-range vehicle which can provide video reconnaissance for upto 150 km behind the battle line for many risky missions including battle damage assessment, individual chemical agent detection (ICAD), etc. Figure 5.14 is a typical scenario, showing employability of one such UAV named Pioneer. This was put to novel use by the US Army for scouting ingress routes for Apache attack helicopter. The UAV was sent immediately before the helicopter; the crew could watch live video of the approach route and target area, then climb into their helicopter and take off. It was in this war that for the first time soldiers surrendered to an inanimate being. The UAV was observing an Iraqi bunker when some 40 Iraqi soldiers emerged from the entrance waving white cloth and leaflets. UAV's success during the war has opened a very wide area for futuristic applications for C^3I, reconnaissance, targeting, EW, SIGINT, COMINT, battle damage assessment, and most of all, working under hostile chemical/nuclear environment.

IMPACT ON FUTURE WAR

Saddam Hussain's 'Mother of All Wars' ended up as mother of all high technology wars having major impact in future warfare. It has been the testing ground for all sophisticated and conventional weapon systems under adverse environmental conditions—in desert, on sea, and in the air. With the US emerging as the single superpower and bulldozing the United Nations, the balance of power in the world as a whole has undergone a dramatic change. The wars of future may be on the lines of Gulf war, rather than Vietnam or Afghan war. Some of the major lessons learnt from IT angle are given below.

- The 'electronic chip' has brought in the concept of composite air wing by streamlining command, control and information.
- Integration of multiple weapon systems from several nations has become a reality.
- Precision guidance will be essential for all types of weapons including tanks and artillery bombs in future.
- Airborne optically guided bombs will be the order of the day and would be able to pinpoint the target within a few metre CEP (Circular Error Brobability, a measure of a bomb's accuracy).
- Electronic Warfare with a stress on ECM and ECCM will be crucial. A force which is able to neutralize the opponent's radars and communication centres within a few minutes of the commencement of war will most likely succeed. Thus an aggressor will have the advantage against the defender.
- Technical superiority rather than superiority of numbers in land, air and sea forces will be the deciding factor.
- Reliability and maintainability of all high technology weapons, as well as of human beings will play a major role in future wars.
- The futurist technology weapons being planned under SDI will get a shot in the arm and will become operational in future wars.
- Chemical and biological weapons will continue to

be developed and deterrant and antimeasures will be essential.

- The unmanned vehicle technology will stabilize providing a safe mode of gathering intelligence behind the enemy lines and under adverse environmental conditions including chemical, nuclear and biological war conditions.

Those who learn from others' experience avoid tragedy striking them. The Gulf war has very significant lessons for a third world country like India. By no stretch of imagination can we afford the kind of high technology weaponry used by the US against Iraq in the Gulf war. However, certain measures to strengthen effective C^3I are necessary. India can ill-afford to ignore the role of computers, both hardware and software, in various systems/subsystems. India's strength in software to upgrade the performance of existing and future weapon systems must be nurtured to fruition. Modern wars are fought by taking correct decisions in real-time, based on up-to-date realistic information. Therefore information must be available to the users at the right time, at the right place and in the right form. There is an urgent need to tackle the doctrinal, technological and organizational problems at the earliest, so that a solid foundation is laid for building effective Defence forces to cope up with a high-tech war, if it is thrust upon us.

6

Future Trends and Military Implications

GENERAL

The rate of growth in computer technology continues at a very fast pace and the future is very difficult to predict. The phenomenal electronic integration on a single chip continues to revolutionize the computer hardware. Newer concepts in software engineering, providing more versatile software for various applications, are being made available daily. The hardware and software of computer systems appear to be affecting every field, especially Defence applications. A number of major future technology and weapon development programmes in the field of computers are under way in the world, particularly in the USA, which will have major military implications.

FUTURE TECHNOLOGY PROGRAMMES

Strategic Defence Initiative

The USA had embarked upon a *major time-bound* futuristic programme in 1983 called SDI (Strategic Defence Initiative) or 'Star Wars Programme' using computer technology to have an edge over the Soviet Block.

The SDI programme is heavily dependent on improvement in computer technology. The futuristic weapon systems and support technologies for surveillance, acquisition, tracking, kill assessment, directed energy weapons such as kinetic energy weapons; all make extensive use of computer-based information technology to make SDI a reality. Some of the newly developed weapon systems using SDI research were successfully tested during the Gulf war. In fact, the success of high technology in the Gulf war (discussed in Chapter 5) has given a boost to further funding of SDI programme by the US Government. Even as Patriots were intercepting Scuds in Tel Aviv, on 28 January 1991, a ground-based interceptor test vehicle ERIS (Exoatmospheric Re-entry vehicle Interceptor System) was successfully tested for destroying an ICBM. Figure 6.1 shows ERIS in its silo just before launch. The target (Minuteman I) was launched from Vandenberg Air Force base and was intercepted 500 nm from launch site atoll at a height of 3,00,000 ft (270 km). The 'threat' was tracked by various radars and NAVSTAR Global Positioning

System satellites to determine the exact position and velocity. The data was used by ERIS mission control software to compute a trajectory for the interceptor. ERIS lifted off through rain and wind 21 minutes after the target was launched and successfully intercepted the target. Since the relative velocities were 30,000 mph, no explosive or warhead was required for the kill.

Global Protection Against Limited Strikes (GPALS)

Based on the experience in Gulf war, the United States government has given a new focus to SDI *program and is concentrating* on a new programme called Global Protection Against Limited Strikes. While the advanced space-and ground-based interceptors will continue with SDI, a new thrust toward providing near-term protection for troops deployed in the field will be attempted by a programme called Tactical Missile Defence Initiative (TMDI). TMDI will become a focal point for all future theatre missile defence programmes including the US Patriot missile system.

Strategic Computing Initiative

Defence Advance Research Project Agency (DARPA) of USA had a ten-year plan called Strategic Computing Initiative to develop machine intelligence technology. It simultaneously proposed to advance computer technology at several levels—new materials and fabrication processes for creating inherently faster chips, new parallel computer architecture for rapid computation and new software technology for endowing machines with flexible and intelligent behaviour.

High Performance Computing and Communications (HPCC)

To upgrade the capability in High Performance Computing and Communication the United States has enhanced funding by 30 per cent and given three major projects to Jet Propulsion Lab, Goddard Space Flight Centre and Ames Research Centre. High performance computing represents the leading edge for the entire computer industry and is bound to play a very significant role in fundamental scientific research, enabling design and production processes to improve computing power. The major goals of HPCC are given below.

- Interfacing a new generation of scalable high-performance parallel computer and software technology to achieve one trillion computer calculations per second. This will make the computers 1000 times faster than at present and will be useful in 'grand challenge' applications.
- Developing a national research and educational network to connect universities, high schools, research laboratories and industry by networks with data speeds of one billion bits per second.
- Educating scientists, engineers and technical personnel to use such powerful capabilities.

Neural Network and Fly-by-Speech

As seen in Chapter 1, the 8-bit processors of early 1970s had a speed of 10,000 operations per second. At present we have 64-bit computers capable of one billion operations per second (Fig. 6.2). The supercomputers under development will be 1000 times more powerful than the current systems and could be put on board the airborne early warning and control aircraft in the near future. Neural networks allow computers to work like the human brain, training them to recognize a particular voice and the correct pronunciation of words. Technology is already moving out of the research laboratories into practical applications, mostly in Defence. Neuro-computers will be able to undertake highly complex tasks which are extremely difficult to perform with current computers. Research is concentrating on image processing, target and feature recognition and it is hoped that a neuro-computer will be able to distinguish between United States' M1 A1 against Iraqi T-72 tanks. The future brilliant weapons will incorporate neuro-computers for selection of suitable target after the missile or some craft is launched.

Flight testing of Fly-by-Speech (FBS) system has already been completed and the first prototype is likely to be installed on European Fighter Aircraft (EFA). The system will have software for Direct Voice Input (DVI) for fighter communication and audio management units. This will enable the pilot to issue verbal instructions to a wide array of key instruments for controlling the aircraft. FBS is bound to have tremendous implication in future warfare.

Virtual Reality

Another area of future research being undertaken for NASA is in the area of virtual reality. This covers the whole range of computer-generated alternate realities which according to experts will be possible before 2000 AD. Virtual reality will have the ability to create an artificial world and have people interact with it so that real-time situation is created. In fact, it is predicted that by using virtual reality goggles connected to a 3D model, a vacationeer will be able to tour distant lands complete with sight, sound and smell from his own living room. The future military applications of this high technology research are unimaginable at present.

Software Automation

With improvement in software technology and availability of a large number of CASE tools, every effort is being made to reduce dependence on manual effort in producing reliable operational software. Software automation offers the biggest time saving for electronic displays and real-time applications. Though a number of automatic software efforts are being attempted, one recent success story has been the development of real-time operational software for Airbus A-340 by Virtual Prototype of Canada, Sextant Avioniques and Aerospatiale of France. These companies have successfully developed electronic displays for aircraft by automatically generating software code embedded in the chip for control of displays. Using the processor they have already delivered intermediate version semi-smart display for Airbus A-340. The system is known as Virtual Avionics

Prototype System (VAPS), which allows the designer to quickly construct workstation pictures of cockpit instrument guages and dials. Figure 6.3 shows a technician using VAPS images. Figure 6.4 shows a graphic screen, where the data is automatically converted into software and embedded into the chip for control of the electronic subsystems. Northrop was the first VAPS customer and is now using the same for B-2 bomber, as well as Y-22 fighter aircraft under development. The concept behind VAPS is that, it is easier to draw a picture of a display than to describe it with words. While the designer is creating animated display, VAPS captures the technical data which then become specifications for the instrument and its performance. The specifications need to be really good, because there is no checking between the specification stage and the incorporation stage. Once the source code is generated, it is translated into machine code and burnt into the chip. Thus the automatic code generation will increase the profitability of software of electronic displays manifold. Similar efforts are being made by computer scientists to generate automatic software with minimal manual interactions. The success in this area will have far- reaching implications in software design of future weapon systems. At present 80 per cent of the effort in any computer- based weapon system design is in the area of software development.

DEFENCE PROJECTS

Strategic Computing Initiative

DARPA's technology development plan envisaged three Defence 'mission programmes' that were to focus on the development of an autonomous land vehicle (Army), a pilot's associate (Air Force) and an aircraft carrier battle management system (Navy). DARPA was more interested in technology development rather than in actually delivering the 'prototypes'. The brief mission profiles of the projects are as follows.

Autonomous land vehicle. The autonomous vehicle application is designed to foster experimentation with robotic devices that would sense and interpret their environment, accept high-level commands and plan their way around an obstacle to carry out their mission. It has demonstrated an impressive set of capabilities and techniques including image understanding, situation assessment, adviser system, intelligent route planners that use digital terrain databases, vehicle state assessment, control techniques, tele-operative vision system and advanced manipulation technology.

Pilot's associate. The pilot's associate was characterized as a sort of R2D2 (of *Star Wars* film) for a combat pilot, that was to be programmed and debugged by pilots during real and simulated test flights. It could perform routine tasks, as well as prearranged functions like manoeuvring to escape interceptor missiles. The project involved development of sophisticated user interfaces for speech and visual communication with the pilot.

Aircraft carrier battle management system. The aircraft carrier battle management system was to test the utility of using machine intelligence to aid in the management of large military engagements. It basically involved decision making under uncertainity and resolution of multiple, conflicting goals.

Advanced Weapon Systems

Satelite/spacecraft/radars. There are a large number of space-based research programmes primarily oriented towards Defence applications. A project for developing tactical satelite (TACSAT) for providing higher imaging capability, radio intercept, communication, varied surveillance, satellite capabilities is the driving force for military space technology development. Low power Atmospheric Compensation (LAC) satellite, using ultraviolet plume imagery for future military surveillance spacecraft will provide all-weather capabilities, instead of complex infrared system. With over 40 successful launches of space shuttle programme, major experimentation in SDI would lead to a number of space-based weapon systems, including high energy X-ray lasers, chemical lasers and neutron beam weapons. This continuing program is providing the United States with major upgradation of their military hardware in space. As demonstrated during the Gulf war a major element of C^3I, JSTARS, had played a pivotal role. Its Synthetic Aperture Radar (SAR) is proving to be particularly valuable and is very useful for tracking moving targets. The improvement in radar technology including space array radar will find its application in almost all weapon systems in Defence.

Stealth bomber. Though the B-2 stealth bomber missed the bus in the Gulf war, the flight and ground testing of augmented B-2 bomber designed by Northrop, is undergoing extensive testing. Several modifications have been made to improve engine performance, and reliability of aircraft handling.

Figure 6.5 shows a prototype B-2 aircraft being taken out of hangar for testing. There have been also major computer hardware and software modifications to improve the performance of this Rs 400 crore bomber. Before the system is made operational, another 36,000 hours of ground-based logistics testing has to be conducted, apart from 20 test missions per month. There is extensive monitoring of various parameters by sophisticated computer-based display system shown in Fig. 6.6. Test aircraft telemeters 8000 parameters to the ground, where these are processed and displayed in near-real-time for immediate review. Recording of these test data generates about 150 standard magnetic tapes per mission. The complexity and enormity of weapon R&D can be gauged from the volume of data and sophisticated processing and displaying on latest graphic workstation of Fig. 6.6.

Advanced Tactical Fighter. In spite of enormous funding by US Government, their Advanced Tactical Fighter (ATF) to replace the existing F-15 or F-16 is nowhere in sight. Two major contenders, i.e., Lockheed and Northrop are in the run for full-scale development of their YF-22 and YF-23 aircraft respectively. These ATFs have sophisticated flight control system based on the latest computer hardware and use millions of lines of code for their efficient performance. These aircraft are all being made for short take off, vertical landing and would have the most sophisticated weaponry including SLAMS, laser guided bombs. Figure 6.7 shows YF-22 during demonstration flights.

Unmanned Aerial Vehicles. With the success of Pioneer during the Gulf war, there is extensive pressure to improve the performance of such systems for dedicated battle damage assessment and other hazardous tasks. The Advanced Tactical Reconnaissance System (ATARS) is the next generation of UAVs for Navy and Air Force. The existing cameras will be replaced by sophisticated sensors, using electro-optic charge coupled device (CCD), in the visual spectrum . The images would be data linked from onboard computer to the ground station computer for real-time analysis of the battle field. The long range oblique photography (LOROP) used for high altitude aircraft, as well as manned platform, will be further improved to give better pictures of the battlefield.

COMPUTER RESEARCH

Major Areas

The major part of the above-mentioned time-bound projects involve large computer reseach programmes in the areas of image processing, speech recognition, natural language processing, expert systems, Artificial Intelligence, machine hardware, software and microelectronics. The major areas of future computer research are discussed in the following.

- **Expert system.** The main objectives of the expert system research is to develop knowledge-engineering tools necessary for battle management system.
- Image understanding. The research effort involves development of algorithms to find range,

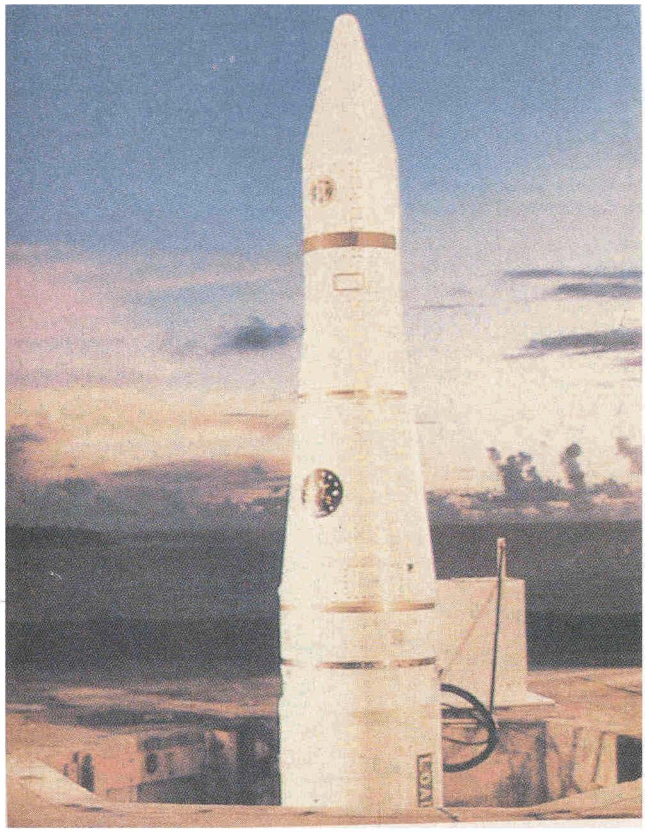

Fig. 6.1 Eris stands in its silo

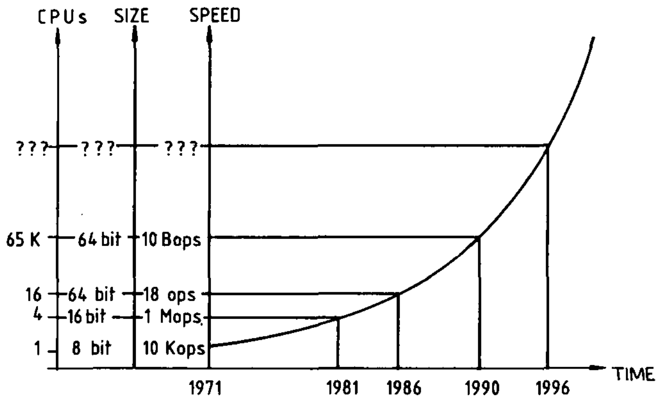

Fig. 6.2 Microprocessor progress during last two decades and their future

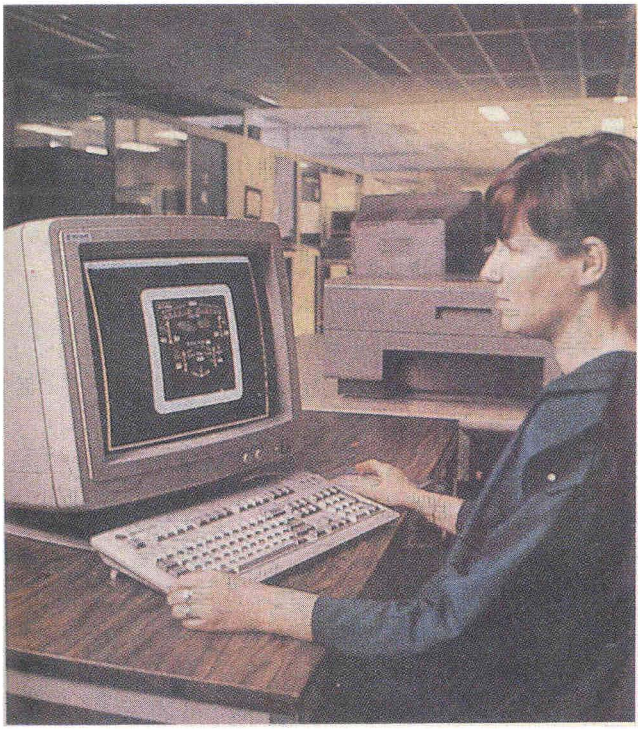

Fig. 6.3 Sextant Avionique technician uses VAPS software to create a graphic of a cockpit instrument on a workstation

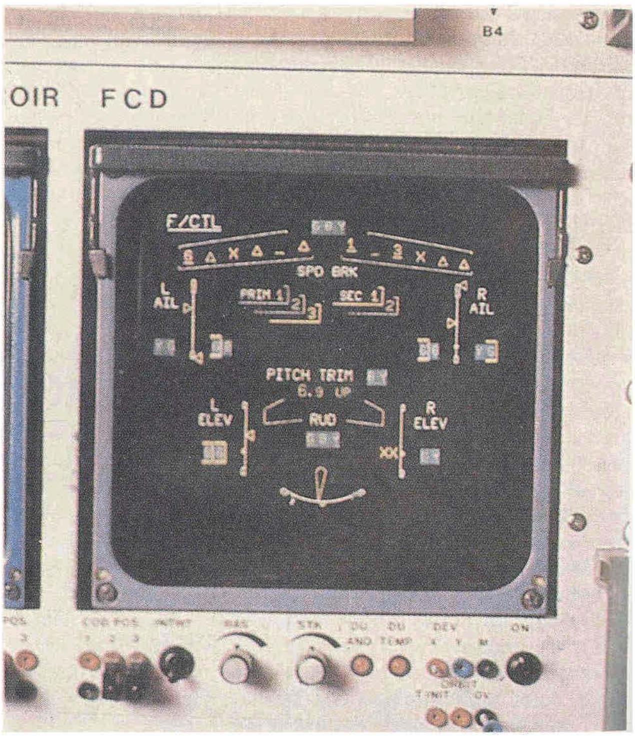

Fig. 6.4 Graphic of Fig. 6.3 is converted automatically to software and embedded into a chip to control the electronic flight display

Fig. 6.5 B-2 operates from Edwards AFB Combined Test Force facility

Fig. 6.6 Latest sophisticated graphics workstation

Fig. 6.7 YF-22 Aircraft during demonstration of flight

terrain modelling, classifying object shapes and surfaces, using several spectral ranges. High-speed parallel architecture computers capable of processing one trillion instructions per second will be needed for image processing, based on these algorithms.

- Speech production and understanding. The research in the area of speech production and recognition entails different levels of noise and stress environment. The limited vocabulary is required to be expanded over the period. The computational requirement for such systems will increase from four to twenty million inferences per second.
- Natural language subsystem. The research in this area encompasses linguistic user and context modelling, language generation and common sense reasoning. Here again the computation speed of a billion inferences per second will be required.
- Hardware and software. The Strategic Computing Initiative programme visualised a 20-30 per cent improvement per year in the computing power of computer systems. It aimed at development of new experimental computers that could achieve high speeds through parallel computation. New concurrent computers would be built specifically for signal processing, symbolic processing and multi-function processing.
- Microelectronics. The present growth of computers has been made possible primarily

because of the exponential improvement in microelectronics. Major thrust will be made in areas of gallium arsenide, memory technology and high performance technology.

Expert Systems and Artificial Intelligence

Expert systems have been a significant aspect of artificial intelligence research for many years and a small number of systems have been in operation for some time. They are already starting to have a general impact in a large number of areas including Defence. Expert systems are the products of the application techniques of AI to a specific field. An expert system is basically a computer system, which has assimilated some of the expert knowledge of a specialist, say an experienced general.

All expert systems operate on a knowledge base, which is generally updated as each new case is dealt with. Most have a set of rules expressing the tricks of the trade. They have control techniques for applying these rules to the knowledge base in order to solve any complex problem. The present systems have confined domains, where knowledge is well structured. In the futuristic expert systems these constraints could be relaxed to a large extent. It should be possible to design an expert system for use in a field (such as battlefront) where the knowledge base is very large, the knowledge may be vague, incomplete and contradictory and situation may change during its analysis by the expert system. The future for AI and expert systems is unlimited, as major research programmes are in advanced stages in research laboratories and academic institutions.

MILITARY IMPLICATIONS

Weapons

Military applications are one of the largest areas for use of futuristic computer technology. The weapon systems of tomorrow will be supplied with increased on-board intelligence called 'brilliant weapons' as against the smart weapons of Gulf war. An intelligent cruise missile would be able to vary its course according to conditions encountered en route, to take evasive action against missile defence systems and choose an alternate target according to tactical decisions made during its flight. Similar improved smart guidance systems on larger or smaller scale are certain to be fitted to torpedoes, anti-aircraft missiles, anti-ship missiles and ICBMs. As an offshoot of SDI, military giants are bound to use a combination of satellite-based and ground-based weapons, using lasers and other high-energy beam sources to destroy a large number of incoming missiles in flight. GPALS will soon be a reality and all major countries may have to alter their Defence strategies.

Command, Control and Communication Systems

Military command, control and communication systems will be increasingly computerized and the availability of computers with enhanced intelligence will enable new generations of these systems to be produced. Many of these systems are likely to be voice activated, following a tradition already established for submarine control. The very first application of electronic computers, cracking the codes of enemy communications, will benefit greatly from computer research and it will cope with natural language. Interactive tactical and operational decision-support systems will assist the work of commanding officers at various levels. Electronic Warfare—where each side attempts to intercept and disrupt the command and communication system of the enemy—will take on a new dimension, as more computers capable of making intelligent decisions at electronic speeds, are introduced. The first step in this was amply demonstrated during the Gulf war, where within a few hours of the air battle, Iraqi EW capability was completely crippled.

Defence Applications Areas

The futuristic computer technology is poised for an exponential growth and will have major military implications. Some of the important areas of Defence applications are as follows.

- Autonomous vehicle for Army, Navy and Air Force for their utilization in extremely hazardous and risky environments.
- High performance processors and software linked by reliable communication network, essential for achieving a responsive,. reliable, survivable and cost-effective battle management system.
- An expert system for diagnosis and maintenance of sophisticated weapon systems like radars, missiles, etc.
- Corps and Division level wargaming simulation for more effective training and evaluation of field commanders.

- Image understanding for target identification and classification. AI techniques to automate the extraction of low level map features for imagery.
- Expert system to assist junior commanders carrying out more accurate appreciation in different battle situations.
- Missile range and trajectory analysis and simulation to assist in qualifying missile performance, as well as ensuring better effectiveness of the same in various environments.
- Logistic management is an important area, where new technology will be able to contribute by making available latest status and various options for meeting the changing requirements of battle.
- Using VHSIC for vital EW applications such as to increase the components in airborne jamming pods for fighter aircraft Guided bombs that can hit their targets unassisted, well after the aircraft that dropped them has escaped enemy anti-aircraft measures can also be made with VHSIC technology and is likely to improve SLAM performance further.
- Natural language and speech interface in weapons can have wide applications in India (where the soldiers are from different parts of the country), and their utilization in weapon systems.

Whether or not the high performance computers or 'Star Wars' programmes are successful, these are going to revolutionize the computer technology in the next decade. Even a partial success in these programmes will have enormous consequences. These will definitely promote widespread use and evaluation of knowledge engineering techniques, which will have far-reaching impact on all Defence applications.

7

Indian Scenario

GENERAL

The information revolution brought about by the computer technology during the last forty years has changed the world more than all the earlier nineteen centuries did. India has also been affected by the miracle chip but not as much as the rest of the world. The national computer policy has been one of caution; thereby controlling the computerization of the various sectors. The available computers have always been years behind the ones available in advanced countries. The computer industry has been starved of the basic inputs and so has not been able to deliver the goods in this fast-changing environment. The computer systems available to the Defence Services have mostly been older versions forming part of imported weapon systems.

NATIONAL SCENE

Computer familiarization came to India in the early 1960s with Honeywell 400 computers in the Government, apart from some second generation systems available to educational institutions. The indigenous effort started with the manufacture of the TDC range by Electronic Corporation of India Limited. This minicomputer was provided to most of the Universities and other Government agencies for limited data processing. For important scientific applications, a very small number of mainframe systems like CDC Cyber-170 and IBM-360 were imported on case-to-case basis.

No serious efforts were made to update computer technology till 1988 when the Government decided to allow transfer of technology agreement for mainframe and supermini computer systems. Meanwhile microcomputer industry brought in a variety of 8-bit and 16-bit small systems within easy reach of various business and individual users. With the PC explosion, the effect was felt at all levels. A number of opportunist industrialists jumped into the fray by providing micro and mini systems to computer enthusiasts by what is now known as the 'screw-driver technology'. Available hardware and software are discussed in the following.

Hardware

The existing industrial infrastructure in the country, both in public and private sectors, has made the following systems available to computer users.

Mainframe systems. Apart from a variety of imported systems, CDC Cyber 180/930 mainframe system is being manufactured under the transfer of technology agreement in the Government sector by ECIL. With a liberalised policy, some more computer vendors are likely to go in for 32-bit mainframe systems in future.

Supermini systems. ND-500 series of 32-bit supermini computer systems of NORSK Data, Norway, are available under licenced agreement through ECIL. A number of other leading computer firms like ICIM, HCL, PSI, DEIL, HP and Wipro are also manufacturing 32-bit supermini systems.

Workstations. The Indian computer market has been recently flooded with a large number of powerful workstations based on SPARC (Scalable Processor ARChitecture). The SPARC architecture using RISC features has limited instruction set and register-based windowing mechanism to give high performance floating point operations. In fact, a power improvement of five to ten times the conventional processors in scientific applications is achievable by these graphic workstations. Major national computer vendors like CMC, HCL, Wipro, HP are competing with one another to meet the growing market of dedicated graphic workstations for CAD/CAM/CAE. All these workstations are primarily copies of their powerful counterparts announced in USA only six to eight months earlier. All types of powerful scientific packages including GKS 2000, ANSYS and electronic design board software are available on these machines.

Personal Computers. The earliest IBM PC machines were based on 8-bit 8088 processor having both data and instruction bus of 8 bit. With the introduction of 8086, a 16-bit processor, the bus width remained 8 bit. A majority of PCs available in the country are of 8088 vintage. With the introduction of 80286 processor providing 32-bit power for IBM PC AT, the bus width still remained 16 bit. It was only with the introduction of Intel 80386 that full 32 bit both for data and address was available on PCs. With the availability of 486 processor having mathematical coprocessor integrated, the power available with a desktop computer system in the country has become manifold. Indian vendors have recently incorporated the Industry Standard Architecture (ISA) in powerful microcomputers by providing EISA (Extended Industry Standard Architecture) bus. These enhancements have been made possible by indigenous R&D by major computer vendors in the country.

Software

India claims to have the third largest scientific manpower in the world. The area of software development, which is manpower-intensive, is an ideal thrust area in computer technology. The national computer policy is also laying stress on this. A number of software business houses are doing yeoman service in developing software for different systems for complex applications. To share the scarce computer resources, national computer networks like ERNET, BANKNET, INDONET and NICNET are being made available. The presently available software are as follows.

UNIX and C. Most of the Indian supermini or mini computer systems have switched over to the international standard, i.e., UNIX Operating System. In fact, an Indian UNIX User Group (IUUG) has been registered and a full office of UNIX has become functional in the country. UNIX Operating System is becoming very popular with its latest releases SVR 3.2 and SVR 4, providing additional features for all computer systems. C language, though not very popular with business community, is making inroads into scientific applications where there is a need to get additional performance by accessing bytes/bits in computer systems.

Computer-Aided Software Engineering. A large number of major software projects have remained non-starters and the bulk of the Indian computer industry has not yet switched over to Computer-Aided Software Engineering (CASE). Among the major reasons for this are, non-involvement of senior management, unrealistic expectations, lack of integration and non-adherence to standard practices. Though enormous efforts are being made in training young computer scientists in well-established software engineering practices, like structured system analysis design, modelling/prototyping and proper documentation, very few users have adopted the same. A large number of CASE tools have been made available to computer users to assist in undertaking major sofware projects. In fact, the indigenous effort by TELCO in promoting a cheap and useful CASE tool (Turbo Analyst) needs special mention. In case the national software efforts have to lead to fruition, the software industry must adhere to the international standards and follow the case meticulously.

Major software systems. During the last 20 years a large number of small and major industry groups have been developing various softwares; but very few of these have been accepted within or outside the country. However, a recent major effort by CMC Limited in providing the rail reservation software—Integrated Multi-train Passenger REServation *System (IMPRESS)*—needs special mention. The software has been transported on different mainframe systems and implemented in all major metropolitan cities to undertake a large number of transactions with success. The earlier effort by ECIL in making the fingerprint detection system for the Police department has also paid dividends. However, *due to its implementation on TDC range of* computer system, the total impact has not been felt. Effort by National Informatics Centre in its four regional centres in developing major software for the national database is also taking shape. In fact, their satellite links and availability of small computer systems at district headquarters was fully tested during the 1991 *Parliamentary elections.* The *Planning Commission* has already cleared Rs 400 crore to link 5500 blocks covering 5.5 lakh villages by computers and satellite links through NICNET. On an experimental basis, *NIC has already connected 440 district headquarters* in 32 states and Union Territories to their computer networking. NIC is also planning to launch its own

NICSAT system to give national coverage to the computer network.

Software export. The Government of India has set a target of US Dollars 400 million for software export for the year 1991-92 for the country. This goal is far beyond the realm of realism, since during the last year of the Seventh 5-year plan, the target set for export was Rs 300 crore, but only Rs 160 crore was achieved. The Department of Electronics has been trying to provide various incentives and has been trying to streamline the procedures; but the result has been marginal. In fact, the concept of setting up regional software parks in Bangalore, Bombay, Calcutta, and recently at Bhuvaneswar and Hyderabad, has been motivated by the urge to use available trained manpower in the area of software for developing international standard software and exporting to the West. The entire software community has to be motivated if computer software strength available in the country is to yield results.

HIGH-TECH COMPUTER RESEARCH

Fifth Generation

India had also entered the race for Fifth Generation computers with the clearance of a major programme by the Planning Commission. The programme is also supported by UNDP and would cost five million US Dollars, apart from Rs 14 crore. The Department of Electronics is the main coordinator of the programme: The main establishments and their areas of research are as follows.

Organization	*Major Areas*
Tata Institute of Fundamental Research, Bombay	Speech Processing System
National Centre for Software Technology, Bombay	Software Engineering and Programming Language
IIT, Madras	Expert System
Indian Institute of Science, Bangalore	AI Parallel Architecture and Graphics

Parallel Computing

The major objectives of the mission envisaged are

- To build a parallel computing system with associated software to solve numerical-intensive problems in science and engineering.
- To create research groups of scientists and engineers, who would develop new parallel computing algorithms and application software to utilize parallel computers effectively to attain their potential performance.
- To create a group of software scientists to restructure and transform existing large (sequential) application programs in a semi-automatic way for execution in parallel machines.

A number of Government agencies have been involved in developing parallel computers to provide powerful computing capabilities for scientific applications. The major agencies and the present state of development is given here.

National Aeronautical Labortory (NAL). NAL built the first parallel processor in India. Based on the Multiple Instruction Multiple Data (MIMD) architecture, the machine, named MK-2 Flowsolver, supported four sets of memory modules connected by a standard IEEE P 796 bus. The CPU modules consisted of 80386 processor and a 80387 numeric processor. The system had two modes. The host processor had 4 Mbytes of main memory The other three processors had 2 Mbytes of memory each. The processors in each mode were coupled by shared memory. Intermode communication was achieved by using parallel ports on Intel memory cards. The number of processors have been increased. It is a special purpose parallel processor for fluid dynamics.

Centre for Development of Telematics (C-DoT). Its parallel processing efforts are also on MIMD architecture. C-DoT aims to deliver a system with 256 processing elements with a sustained performance of about 200 MFLOPS. The system uses a variety of processors including CMOS (Complementary Metal Oxide Semiconductor) chips and even a T-800 transputer. A time-space-time switch and global memory are other highlights. C-DoT aims to deliver the full-fledged system by mid-1991. The machine on completion will cater to the needs of the Giant Metrewave Telescope Project of the Tata Institute of Fundamental Research.

Centre for Development of Advanced Computing (C-DAC). Param, the lone offering of C-DAC, is based on MIMD message-passing architecture. The prototype, unveiled in 1990, has 64 T-800 nodes. A 32-bit integer processor, 64-bit floating point processor in each node, and a 25M bytes/s memory bandwidth are some of the listed features. A 256 node machine capable of a peak computing power of 1,000 MFLOPS is being targeted at the end of the final phase of the project. The 64 node Param is capable of a peak of 100 MFLOPS, and uses Transputer Development System (TDS) systems software. Applications claimed include weather forecasting, oil exploration, signal processing, VLSI design, speech recognition, computational physics, computational chemistry, material sciences and artificial intelligence.

Central Research Laboratory (CRL), Bharat Electronics. It has built a 64-node parallel signal processor based on T-800 transputers. In Param, the four communication channels of each transputer are linked to crossbar switches, while in the CRL's system only two of the links in each transputer are connected to a crossbar switch and the other two are preconnected in the form of a pipe. Param has extra hardware like the 'byte bus' which provides certain diagnostic functions. This is absent in CRL's machine. Param also has I/O nodes connected to disks and a file system. The parallel signal processor took three man-months of effort. In terms of computational power, this machine is claimed to be as good as Param. The machine finds use in radars and other systems that involve complex signal processing.

DEFENCE SERVICES

Defence Services in India have always remained in the forefront in making use of the latest technology for meeting their tactical and operational requirements. All the three Services have well-established computer centres for training their officers and staff in various applications using computers. A major thrust has been in the important area of management and MIS. In weapon systems, Army, Navy and Air Force have been heavily dependent on imported technology and weapons. For development of indigenous weapon systems designed by Defence Research and Development Organisation, microcomputers have been extensively used for on-board and real-time applications.

The Defence Services are making extensive use of satellite links for their command and control applications, with field formation. Though an integrated C^3 I is yet to be fully developed, efforts are on hand to provide an efficient communication link between forward troops and Divisions, Corps, and Command HQrs. Efficient inter-Services communication is also operational for sectorwise operation, in case of war. To train a commander in wargaming and simulation, extensive use of computers is being made at different training establishments. The sand model exercises are gradually being replaced by computer generated imagery and more realistic manipulation of forces during exercises. Computer systems are finding their places right from Battalion level for various operational and logistic applications by the Services.

DEFENCE RESEARCH & DEVELOPMENT ORGANISATION (DRDO)

DRDO has major projects and programmes to provide Defence Services the Main Battle tank (MBT), Light Combat Aircraft (LCA) and a range of sophisticated missile systems. This is being achieved by the major efforts of over 40 DRDO laboratories coupled with help from leading industries and educational institutions, including IITs. In the national quest for a self-reliant defence posture, DRDO endeavours to provide the research, design and development base for meeting the needs of the Armed Forces—needs ranging from aircraft, missiles, torpedoes, radars and tanks to frozen foods and nuclear medicines. All this is being made possible by extensive use of computer technology at all levels.

Major Programmes

Some of the major development programmes being undertaken by DRDO are described in the folowing.

Main Battle Tank Arjun. During the last 15 years DRDO has been able to develop their own main battle tank Arjun, which is likely to replace the existing Soviet T-72 tanks. The tank is in advanced stage of development and a number of these tanks have been undergoing user trials. Figure 7.1 shows a view of Arjun under cross-country trials.

Integrated Guided Missile Development Programme. Since 1983 an Integrated Guided Missile Development Programme (IGMDP) has been in progress with various work centres of DRDO. The programme consists of *Trishul,* a short range surface-to-air tactical missile, *Prithvi,* a surface-to-surface battlefield tactical missile, *Akash,* a medium range air defence system and *Nag,* an anti-tank missile of the fire-and-forget type. The technology demonstrator *Agni* was succesfully flight-tested in 1988. *Prithvi* is shown in Fig. 7.2 on its mobile launcher.

Light Combat Aircraft (LCA). Aeronautics Development Agency (ADA) has been entrusted with the responsibility of development of LCA for meeting the futuristic requirement of the Indian Air Force. A number of collaborative efforts for incorporating a powerful engine have been in progress and it is hoped that the first LCA prototype will be flown before 1995.

Naval Ships. Indian Navy in collabration with DRDO has also undergone a 'maritime renaissance' both by acquisition as well as by construction of new ships. It is now the eighth largest Navy in the world. Figure 7.3 shows *INS Godavari,* one of modern frigates made by indigenous R&D. A number of Naval projects are also in progress to meet the growing need for defence of the long Indian coastline.

COMPUTER R&D AND APPLICATIONS IN DRDO

DRDO has a large number of well-established laboratories spread throughout the country. Each laboratory has its own well-equipped computer facility for its dedicated use. Though it established four regional centres at Delhi, Hyderabad, Bangalore, and Pune, these have subsequently been merged with local establishments. The trained specialized computer manpower with the computer centre teams are being utilized to take on dedicated software development work in relation to ongoing Defence projects. With the availability of powerful stand-alone workstations, the concept of large regional centres has been given up thereby distributing the computing resources among the various establishments.

Advanced Numerical Research and Analysis Group (ANURAG)

DRDO has established a dedicated group of young scientists to undertake the challenging task of developing supercomputer capabilities inhouse. The group started functioning in 1987 in the premises of Defence Research & Development Laboratory, Hyderabad and is now called Advanced Numerical Research and Analysis Group (ANURAG). In a short span of three years, the group has already successfully demonstrated a powerful parallel processing system based on hypercube architecture. ANURAG is following the policy of configuring their powerful parallel computer using off-the-shelf microprocessor with total indigenous effort. The Processor for Aerodynamic Computational Evaluation (PACE) is based on Motorola 68030 (33 MHz), with floating point accelerator Motorola 6882. A LIN-PACK rating of 1.84 MFLOPS has been achieved. The group has already designed their powerful coprocessor ANUCO for further accelerating power of the system. It will increase the power of a 128-node system to over 100 MFLOPS. A number of machines are already under use in DRDO. At present FORTRAN, C, PASCAL are being made available through ANURAG's Parallel Application Manager (ANUPAM). Apart from hypercube manager and run-time front-end system working on UNIX V.3, it also supports mapper debugger and other utilities. Nodal operating system on hypercube is PSOS, providing multi - tasking, inter-task, inter-processor communication.

The designs for vector processing, as well as string matching modules are in advanced stages of development. ANURAG has been interacting with Electronics Corporation of India Limited for productionization of their design and subsequent marketing. The group will soon be able to take on additional high-tech computer-related research leading to fulfilling the much-needed requirements of DRDO and Defence Services.

Centre for Artificial Intelligence and Robotics (CAIR)

A Centre for Artificial Intelligence and Robotics (CAIR) has been established to develop knowledge-based systems for the specific requirements of the Services. This centre coordinates the major development programmes in the field of applications of AI for Defence requirements and is the AI resource centre of DRDO.

Systems development programmes aimed at delivery of systems employing AI technology to enhance the Defence capability are being taken up. This would require a technology base such as intelligent functional capabilities, hardware, software, systems architecture and microelectronics. The technology base in turn will need infrastructure in terms of high-speed computers, foundries, design tools, rapid prototyping techniques, etc. The key thrust areas in developing a technological base for intelligent functional capabilities are

- Expert Systems
- Data fusion
- Machine vision
- Speech recognition
- Natural language understanding
- Planning and reasoning

MIS and Decision Supporting Systems

DRDO has implemented a project management information system at the Headquarters level for major projects and programmes. A decision support system for manpower planning, development and growth, financial resource management and allocation is also being implemented. However, these will have to be further refined or modified keeping in view the requirements of the users. The information system will be developed to help in monitoring of information at the macro level, as well as at the micro level. The information system developed is menu-driven with excellent query features. The information can be had discipline-wise, user-wise, cost-wise or a combination of discipline and user.

Manpower Development Programme

The necessity to have trained manpower in the field of computer science needs hardly any emphasis. If the DRDO laboratories are to succeed in their major development programmes, it is necessary to create a pool of trained manpower which will be available for carrying out the development of various time-bound programmes. Accordingly, DRDO has taken the initiative in the development of trained manpower in various academic institutions all over the country.

Defence Research and Development Organisation has a large number of Fellowship schemes with major educational institutions like IITs, Indian Institute of Science and major universities to train specialist manpower needed for Defence projects. The Electronics Fellowship Scheme primarily looks after the electronics requirement. Similar schemes in aeronautics, mechanical engineering and other disciplines for IGMDP and other programmes are also in existence. One of the novel experiments for attracting budding computer scientists was undertaken by DRDO with eight selected universities by sponsoring their selected candidates for M Sc (CS) scheme. A number of computer scientists have graduated from this scheme and are now employed on various projects in different Defence laboratories.

MANPOWER DEVELOPMENT OUTSIDE DRDO

The Government of India has formalized a scheme for developing trained manpower to meet the growing requirement in the field of software development and applications. The Department of Electronics (DOE) will be the nodal agency for the scheme and will be empowered to accredit private training institutes to run training courses.

In the first instance, an '0' level scheme has been started in consultation with the Computer Society of India (CSI). The level of specialization needed after the 10+2 stage has been specified. Examinations will be held every six months by CSI. Students will be trained by the recognized institutions to appear in these examinations. Since these examinations are recognized by DOE, succesful students will be eligible to apply for government jobs in the area of computer application.

Similar schemes for 'C' level for system analysts is likely to be finalized with the Institute of Electronics and Telecommunication Engineering in the near future. With the implementation of these manpower generation schemes, it is hoped that well-equipped and trained manpower required for developing international grade sofware would become available.

CONCLUSION

Whatever the technology produces, it is certain that one problem is going to get worse. We can speed up computers almost without limit, but the human mind still plods along at its accustomed pace, and unless we are willing to take the enormous risk of surrendering our authority to machines, the critical decisions must still be made by human beings. In the last two years, the Gulf war has provided us with two examples of this kind of dilemma. Vincenne, which reacted too quickly and the Stark which did not react quickly enough. These two incidents have given reminders that, although computers can give us access to enormous amount of information in a very short time,

Fig. 7.1 *Arjun* Main Battle Tank

Fig. 7.2 The *Prithvi* is an SSM with a range of 250 km due for military service

Fig. 7.3 *INS Godavari*, one of the modern frigates now in service

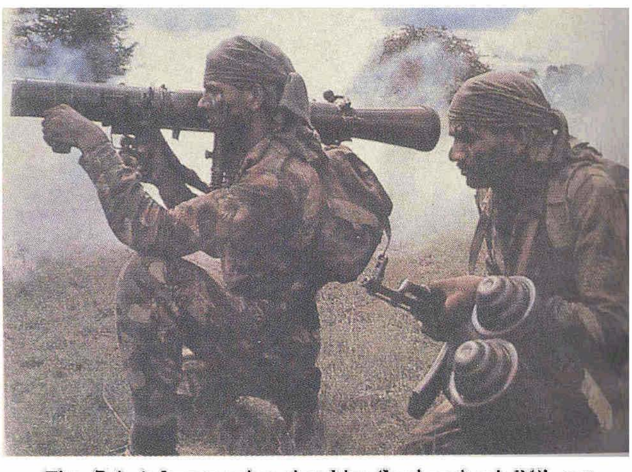

Fig. 7.4 A Jawan using shoulder-fired antitank RCL gun

what we do with that information is strictly upto us. There would have been hundreds of such experiences during the recent 45 days' war between Iraq and international forces where high-tech weapons were put through their first tests.

Computer technology is playing a major role in the areas of Defence applications. The present trend indicates that the high performance computing and futuristic research, AI/Expert systems and allied weapons research will revolutionize all computer operations in Defence. We, in India, will have to face the challenges of computer technology by providing the Defence Services the best possible weapon systems, preferably 'brilliant weapons' at par with the best in the world. With our limited resources, we can ill-afford to buy complete systems. Therefore, we must undertake indigenous development programmes both for hardware and software, to keep pace with the advanced countries After the Gulf war, the scenario has completely changed and we must realign our Defence strategy and tactics to what is realizable within the country and is applicable to us; rather than to look West for what the USA is having. Computer *technology being software-intensive, we must* concentrate on getting better performance by using innovative software, even with inferior hardware. The basic infrastructure exists, both at national level, as well as within the Defence; particularly with Defence Research and Development Organisation. Better utilization of high technology is all that is the needed for providing improved weapon systems to our soldiers, sailors and airmen for defending our country.

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Glossary

ABC analysis		An inventory monitoring technique wherein the stock is divided into three types—A, B,and C—depending on the value. An effective control of the 'A' items, which normally form less than 20 per cent of volume but 80 per cent of value, may be sufficient.
Acronym	:	A word formed from the initial letters in a name or phase. For example, FORTRAN is an acronym for FORmula TRANslation.
Alphanumeric	:	A contraction of the words alphabetic and numeric. A set of alphanumeric characters usually includes special characters such as the dollar sign and comma as well.
Application program	:	A precoded set of generalized instructions for the computer, written to accomplish a certain goal. Examples of such programs include a general ledger package, a mailing list program, and PacMan.
ASCII	:	An acronym for American Standard Code for Information Interchange (pronounced ass-key). Often called US ASCII, this code is a standard method of representing a character with a number inside the computer. Knowledge of the code is important only if one writes programs.

Assembler	:	A program that converts the mnemonics and symbols of assembly language into the opcodes and operands of machine language.
Assembly language	:	A language similar in structure to machine language, but made up of mnemonics and symbols. Programs written in assembly language are slightly less difficult to write and understand than programs in machine language.
BASIC	:	An acronym for Beginners All-Purpose Symbolic Instruction Code. It is a common, easy-to-learn computer programming language. The advanced version of BASIC is called BASICA.
Baud rate	:	The speed at which modems can transmit characters across telephone lines. A 300-baud modem can transmit about thirty characters per second.
Binary	:	A number system consisting of two digits 0 and 1, with each digit in a binary number representing a power of two. Most digital computers are binary. A binary signal is easily expressed by the presence or absence of an electrical current or magnetic field.
Bit	:	A binary digit, the smallest amount of information a computer can hold. A single bit specifies a single value of 0 or 1. Bits can be grouped to form larger values (see Byte and Nibble).

Block	:	A designated portion of text, consisting of one or more lines, that is to be copied, moved, or deleted.
Booting	:	The process of starting the computer. During the boot process a memory check is performed, the various parts of DOS are loaded, and the date and time are requested.
Bootstrap (boot)	:	The procedure used to get a system running from a cold start. The name comes from the machine's attempts to pull itself off the ground by 'tugging on its own bootstraps'.
Bug	:	An error. A hardware bug is a physical or electrical malfunction or design error; a software bug is an error in programming, either in the logic of the program or in typing.
Bus	:	The entity that allows the computer to pass information to a peripheral and to receive information from the peripheral.
Byte	:	A basic unit of measure of a computer's memory. A byte usually comprises eight bits, and therefore its value can be from 0 to 255. Each character can be represented in one byte in ASCII.
Central Processing Unit (CPU)	:	The device in a computer system that contains the Arithmetic Logic Unit (ALU), the control unit, and the main memory.
Character	:	Any graphic symbol that has a specific

meaning. Letters (both upper- and lower-case), numbers and various symbols (such as punctuation marks) are all characters.

COBOL	:	An acronym for *Common Business Oriented Language*. Cobol is a high-level language oriented towards organisational data processing procedures.
Code	:	A method of representing something in terms of something else. The ASCII code represents characters in terms of binary numbers; the BASIC language represents algorithms in terms of program statements. Code also may refer to programs, usually in low level languages.
Communications packages	:	Hardware packages that allow one to obtain and/or transmit information over telephone lines.
Compiler	:	A piece of software that translates a complete program into machine language. As it performs this translation process, it also checks for any possible errors that have been made by the programmer.
Computer	:	Any device that can receive and store a set of instructions and then act upon those instructions in a predetermined and predictable fashion. The definition implies that both the instructions and the data upon which the instructions act can be changed. A device whose instructions cannot be changed is not a computer.

Configured software	:	Software that has been customized to the specific hardware configuration currently used.
Coprocessor	:	A microprocessor chip that is placed in a microcomputer to take the burden of manipulating number off the CPU, allowing it to perform other tasks.
CRT	:	An acronym for cathode ray tube, meaning any television screen or device containing such a screen.
Cursor	:	The display screen's special character (–) used to indicate where the next character will be typed, that is, where one is in a file.
Data (datum)	:	Information of any type.
Data entry	:	The process of placing text, values labels, or formulae into a text document, data file, or worksheet.
Database	:	A collection of data related to one specific type of application. Database is often used synonymously with file.
dBASE II	:	A popular relational data base package.
dBASE III	:	An updated version of dBASE II.
Debug	:	To find bugs and eliminate them.
Default	:	The original or initial setting of a software package.
Directory	:	The part of a diskette that holds the names of any files stored on it. The directory also contains information about the size of the files, their location on diskette, and the dates and times when they were created.
Disk drive	:	A rectangular box that is connected to or is situated inside the computer and

		that reads from and writes into diskettes.
Diskette	:	The record-like object used for feeding data into and for storing information from the computer.
Display	:	Any sort of output device for a computer, usually a video screen. As a verb, means to place information on such a screen.
DOS	:	An acronym for Disk Operation System—the program responsible for allowing one to interact with the various parts of a computer system. DOS (pronounced doss) is the interface between the user and the hardware. DOS commands are typed using the keyboard and allow the user to perform system functions. DOS *is actually a collection of* programs designed to make it easy to create and manage files, run programs, and use system devices attached to the computer.
Double-sided disks	:	Disks that allow data to be stored on both their surfaces. A double-sided disk has been certified (tested) on both sides.
Edit	:	The process by which the form or format of data is modified for output by inserting dollar signs, blanks, and so on. Used as a verb, to validate and rearrange input data.
Editing a document	:	The inserting, deleting or changing of existing text in a wordprocessing text file.
Electronic spreadsheets	:	Programs that allow users to manipulate any data that can be expressed in rows and columns.

Execute : To perform the intention of a command or instruction; to run a program or a portion of a program.

Field : A subdivision of a record that holds one piece of data about a transaction.

File : A collection of data or programs that serves a single purpose. A file is stored on a diskette and given a name so that one can recall it for use at a later time.

File allocation table : The entity that keeps track of which sectors belong to which files and of how much available space remains on the diskette (so that new files can be created and stored in unused areas of the diskette).

File name : The unique identifier of a file, composed of one to eight characters. If an optional one-to-three-character extension is used, there must be a period between the file name and the file extension.

Floating-point arithmetic : A technique in which numbers are expressed as integers multiplied by the radix raised to an integral power. For example, 0.054 will be expressed as $54x10^3$

Floating-point operation : Any operation using floating-point arithmetic.

Font : A character set for printing. Times, Elite, Helvetica, Courier, and Geneva are among the many common fonts.

Formula : A series of characters containing cell references and arithmetic operators for numeric data manipulation.

FORTRAN	: An acronym for FORmula TRANslation, a programming language designed for writing problem-solving programs that can be stated as arithmetic procedures.
Functions	: Built-in formulae or processes already programmed into a software package. These functions save a user a tremendous amount of effort and tedium.
Graphics	: A system used to display graphic items or a collection of such items.
Hard copy	: A printed document on paper.
Hard disk	: A rigid medium for storing computer information. It is typically rated in megabytes (millions of bytes) of storage capacity.
Hard-sectored	: Describes disks that have already had their tracks divided into sectors.
Hexadecimal	: A number system that uses the ten digits '0' through '9' and the six letters 'A' through 'F' to represent values in base 16. Each hexadecimal digit in a hexadecimal number represents a power of 1:
Hierarchical (tree) structure	: A structural arrangement in which data elements are linked together in multiple levels that graphically resemble an organization chart. Each lower level is owned by an upper level.
High-level language	: A language that is more English-like. Programs written in this are machine-independent.
Initialization	: A process during the boot routine when the computer activates the various peripherals hooked to the computer.

Inkjet printer	:	A printer that sprays ink in droplets onto paper to form character. It is much quieter than dot matrix or letter quality printer.
Instruction	:	The smaller portion of a program that a computer can execute.
Integrated circuit	:	A small (less than the size of a finger-nailand about as thin) wafer of glassy material (usually silicon) into which an electronic circuit has been etched. A single IC can contain from 10 to 10,000 different electronic components.
Interface	:	The actual adapter or circuit board containing the electrical components that connect a peripheral with the computer's bus system.
Interpreter	:	A program, usually written in machine language, that understands and executes a higher-level language one statement at a time.
K	:	An abbreviation for the Greek prefix Kilo meaning thousand. In computer related usage, K usually represents the quantity 2 to the power of 10, or 1024.
Keyboard	:	The system hardware used to input characters, commands, and functions to the computer. The keyboard normally consists of 83 keys and is organized into three sections: the function keys, the typewriter keyboard, and numeric key pad.
Label	:	Alphanumeric information used to identify a portion of a row or column.

Language	:	A code that both the programmer and the computer understand. The programmer uses the language to express what is to be done, and the computer understands the language and performs the desired actions.
Laser printer	:	A printer that uses laser technology to electronically form characters on paper via electronic charges and then place toner on the charges to display the characters. The toner is fixed in place via a heat process.
Letter-quality printer	:	A printer that generates output of comparable quality to that produced on a typewriter.
Local Area Networks (LANs)	:	Networks that allow one to onnect a number of microcomputers in order to share data or expensive peripheral devices.
Logged device	:	The disk specified to be searched automatically for any needed files.
Low-level language	:	A language that is written in code. It is machine-dependent.
Machine language	:	The lowest level language a computer understands. Machine language is usually binary; instructions in machine language are single-byte opcodes, sometimes followed by various operands.
Megabyte	:	One million characters of storage—a quantity usually used as a measure of available storage on a hard disk.
Memory location	:	The smallest subdivision of the memory map to which the computer can refer. Each memory location has associated with it a unique address and a certain value.

Menu	:	A listing of commands available to any one using a software package.
Microcomputer	:	A term used to describe a computer that is based upon a microprocessor (8-bit or 16-bit) that can execute a single user's program.
Microcomputer system	:	The combined computer, disk drives, monitor, and input and output devices for data processing.
Microsoft	:	The company that originally developed PC DOS for IBM (an operating system known, with some minor differences, as MS DOS).
Mnemonic	:	Any acronym or other symbol used in place of something more difficult to remember.
Modem	:	The acronym for MOdulator DEModulator. A device that can convert digital computer signals into analog telephone signals and can reverse the procedure at the other end of the line.
Monitor	:	A TV-like device that gives users of microcomputer equipment video feedback about their actions and the computer's actions.
Mouse	:	A hand-held controller that electroni cally signals the computer to move the cursor on the display screen. The same type of actions can be accomplished via the cursor control pad.
Nibble		The slang term for half a byte (four bits).
Nonvolatile storage.		A form of storage that does not lose its contents when the system's power is turned off. It may take the form of bubble memory, or it may be powered by batteries.

Numeric field	:	A field that can only hold a number on a decimal point. No alphabetic or special characters can be placed in such a field.
Object code	:	The machine language code created by the compiler. It is the object code that is actually executed by the computer.
Operating system	:	The interface between the computer and the computer user, which provides the user with flexible and manageable control over the resources of the computer.
Output	:	Computer-generated data whose destination is the screen, disk, printer, or some other output device.
Parallel interface	:	An interface arrangement that transmits all nine bits of a character at one time.
Peripheral	:	Any device attached to the computer that is not part of the computer itself. Most peripherals are input and/or output devices.
Personal computer	:	A computer equipped with memory, language and peripherals, and well suited for use in a home, office, or school.
Pixel	:	A dot that is turned on or off depending on what character is being displayed on the screen.
Plotter	:	A device that allows a pen to move on X and Y axes to draw graphs or other diagrams. For one of the axes, the paper may be required to be moved instead of the moving the pen.
Primary memory	:	Internal memory used by the computer for a number of different functions. It can contain data, program instructions, or intermediate results of calculations.

Printed circuit board		A sheet of fiberglass or epoxy onto which a thin layer of metal has been applied and then etched to form traces. Electronic components are then attached to the board with molten solder, and thereafter they can exchange electronic signals via the etched traces on the board. Small printed circuit boards are often called cards, especially if they are meant to connect with edge connectors.
Printer	:	A device that allows one to maintain a permanent copy of any output generated and to dump that output to paper.
Procedures	:	Written instructions on how to use hardware or software.
Program	:	A set of computer instructions that tells the computer how to perform a certain task. DOS, BASIC, and the instructor are all programs.
Programming Languages	:	A special means of providing instructions to the computer to get it to perform a specific task. Examples of programming languages are BASIC, COBOL, PASCAL, and FORTRAN.
PROM	:	An acronym for Programmable Read-Only Memory. A PROM is a ROM whose contents are alterable by electrical means. Information in PROMs does not disappear when the power is turned off. Some PROMs can be erased by ultraviolet light and then reprogrammed.
Random Access	:	The main memory of a Memory (RAM) computer. The acronym RAM can be used to refer either to the integrated circuits that make up this type of memory or the memory itself. The computer can store values in dis-

tinct locations in RAM and then recall them, or it can alter and restore them if needed.

Read Only Memory (ROM) : The memory usually used to hold important programs or data that must be available to the computer when power is first turned on. Inforamtion in ROMs is placed there during the process of their manufacture and is unalterable. Information stored in ROMs does not disappear when power is turned off.

Record : The entity that contains information about a specific business happening or transaction.

Run : The action of following a sequence of instructions that make up a program to its completion.

Scroll : A function that moves all the text on a display (usually upward) to make room for more.

Save disk : A disk that has been formatted but does not contain the operating system. One cannot boot the computer by using such a disk.

Soft carriage return : A carriage return accomplished by using the word wrap feature. A soft carriage return causes a space to register as the Wordstar flag character for the line on which it occurs.

Soft sectored : Describes disks that have each track divided into sectors during the format process.

Software : The programs that make the computer work.

Source code : The set of program instructions written in a high-level language.

Source drive	:	The drive that contains any files to be copied.
Spreadsheet	:	A software package that can readily manipulate rows and columns of data.
Storage	:	A term that applies to either internal RAM memory or to external disk memory.
Subroutine	:	A segment of a program that canbe executed by a single *call.Subroutines* are used to perform the same sequence of instructions at many different places in a single program.
Syntax	:	The structure of instructions in a given language. If one makes a mistake in entering an instruction and garbles the syntax, the computer sometimes calls this a syntax error.
Text characters	:	Letters and numbers, usually in English.
Thermal printer	:	A printer that generates characters by burning dots *into special* paper.
Track	:	A concentric circle of storage on a disk's read/write surface, along which data is stored.
Video	:	Anything usually information presented on the face of a cathode ray tube.
Volatile memory	:	Memory that is erased when the electrical *current to the computer is turned off.*
Warm start	:	A booting process used to restart a computer after one has lost control of its language or operating system.
Window	:	The currently displayed portion of the worksheet or document. This window can be split into two smaller windows horizontally or vertically.

Wordprocessing	:	The automated manipulation of text data via a software package. Such a software package usually provides the ability to create, edit-store, and print documents easily.
Wordstar	:	A popular wordprocessing package, frequently used in business.
Worksheet	:	A model or representation of reality that is created using a spreadsheet software package. The worksheet is contained inside the spreadsheet border.
Write-protected	:	Describes diskettes that have been protected from having information stored on them, from being altered, or from being deleted; this is accomplished by placing a write-protect tab over the small rectangular hole on the side of a diskette.

The Book

The book covers the fundamendals of computers and their applications, especially in Defence, in a layman's language. The Second Edition of the book has been brought out to additionally cover the role of computer technology in Hi-Tech war, based on the recent Gulf war. A new chapter has been added covering information technology and impact of Gulf war. After a summary of early computing machines that led to the development of computers in Chapter 1, the hardware or the physical parts that make up a computer system are discussed in chapter 2. Here the author describes how the computer works. In chapter 3 the software, which can be thought of as the 'brains' of the computer, are discussed. The current applications of computer technology in the world in the areas of direct interest to Defence Services are covered in Chapter 4.

Most of the predictions made in First Edition have come true and have resulted in computer-based weapon systems. In the ever-changing field of computers, the author has again made an effort at crystal-gazing on military implications in chapter 6. The concluding Chapter 7 is on the computer scene in India — the models of indigenous computers, the available software, research going on in the country in the area of AI, the role being played by the Defence Research & Development Organisation (DRDO)—are all covered. For the benefit of readers normally foxed by the jargon of computer specialists, a glossary of computer terms has been included at the end.

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