A STUDY AND ANALYSIS OF THE INSTALLATION OF A DIGITAL FLIGHT SIMULATOR AT THE NIGERIAN CIVIL AVIATION TRAINING CENTRE ZARIA THROUGH THE TECHNIQUE OF NETWORK ANALYSIS.

BY

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DECLARATION

I hereby declare that this project, which was a record of my research work, has been written by me. It has not been previously presented for the award of any degree.

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CERTIFICATION

This Project report entitled A Study and Analysis of the Installation of a Digital Flight Simulator at the Nigerian Civil Aviation Training Centre, Zaria by Mustapha Bashiru meets the regulations governing the award of the degree of Master of Business Administration (MBA) of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary contribution.

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DEDICATION

To the loving memory of my late mother Hajia Hauwau Basharu and father Alhaji Mohammadu Basharu Maman.ubu.

ACKNOWLEDGEMENTS.

This work has been carried out at the suggestion of Mr. V. Janakiraman, to whom I feel greatly indebted. His suggestions and critiques have been of tremendous help to me. I am particularly grateful to my supervisor and the Head of the Department of Business Administration, Dr. J. G. Donli who has been of great inspiration. I must express my appreciation of the co-operation of the Principal, Nigerian Civil Aviation Training Centre, Zaria and the entire Staff of the Flight Simulator Department for allowing me access to gather data.

To my wife Ramatu and our children, Mohammed, Ibrahim and Halima, for showing love and understanding throughout my study period, it is a big thank you.

Finally, I wish to express my profound gratitude to my brothers Hamidu, Sidiq and Aminu for their unending support and kind desire to make things possible. May Allah guide us all.

ABSTRACT

Modern flying machines are equiped with complex instrumentation and controls, requiring high degree of mastery of use for enhanced safe air navigation. High operating costs and risk to live-equipment have led to the invention of the Flight Simulator, whoso manufacturing fidelity is of such realism that total transitional training may take place in this device. Consequently this high cost machine (minimum about US 28m) demands as much managerial skill as possible in every phase of its cycle, from production to delivery, installation, commissioning and subsequent operations. Installation involves local and foreign labour inputs, use of hired machines and plants.

In 1981, the Nigerian Civil AViation Training Centre, Zaria, installed a Fokker 2B Digital Flight Simulator at their Simulator complex in Zaria. representatives of the manufacturers, Messrs Rediffusion Simulation Limited of United Kingdom, were on site with the Nigerian counterparts to carry out the installation. All costs vrere borne by MCATC. The technique of Network Analysis is hereby applied to the installation in order to reduce installation time and therefore costs. A PERT Network was produced for the project.

The critical paths obtained showed a time saving of 11 days and a cost saving of N40,115.63. Sources of improvements have also been identified.

PREFACE

This work, which involves the study and analysis of the installation process of a digital flight simulator at Nigerian Civil Aviation Training Centre (NCATC), Zaria through the technique of network analysis, is as a result of a joint decision between my supervisor and I. The basis of this decision is the retrospective view of such an installation which was carried out at NCATC, Zaria in 1981.

I participated in the installation of a Fokker 28 Fellowship Flight Simulator, at the facilities of NCATC, Zaria. Various difficulties were encountered that resulted in loss of time, heavy cash expenses, consequently a delayed commissioning resulting in the loss of revenue. It was therefore decided that a cost and time saving proceedure could be evolved which may be applicable to the next flight simulator installation.

Chapter 1 serves as an introduction detailing activities of the NCATC, Zaria with particular reference to the role of the Flight Simulator. A description of methodology is also provided in this Chapter.

Chapter 2 reviews related literature and general theories of application.

In Chapter 3, the analysis and interpretation together with recommendations are provided.

Chapter 4 covers the summary and conclusions.

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CHAPTER ONE

INTRODUCTION

1.1 THE ORGANISATION

1.1.1. Historic Synopsis

Early plans for the establishment of a Civil Aviation Training Centre in Nigeria were discussed at the 12th Assembly of the International Civil Aviation Organization which was held at San Diego, California, United States of America in the summer of 1959. In 1962, the Government of Nigeria requested the services of an International Civil Aviation Organization expert to assist in the preparation of a formal request for assistance from the United Nations Special Fund, and also to investigate the actual requirements for the establishment of the project. In the same year, the official request was forwarded to the United Nations Special Fund and was approved in January, 1963. The Bill establishing the Training Centre was passed by the Nigerian House of Representatives on the 29th of September, 1964, and the Nigerian Civil Aviation Training Centre Act came into force on 23rd October, 1964. The project was thus formulated as a joint project between the Federal Government, the United Nations Development Programme, and the International Civil Aviation Organization.

Since the inception of the Training Centre, the Government of the Federal Republic of Nigeria has been providing the infrastructure, counterpart instructional staff, the administrative and technical staff, furnishings, equipment, insurance and operating expenses. For the recurrent and capital expenditures of the Training Centre, the Federal Government has been making available large sums of money yearly, in accordance with the approved Annual Budget of the Centre.

The United Nations Development Programme has provided over a seven year period (1966-74), a staff of international experts and most of the training equipment. The United Nations Development Programme (UNDP), with the agreement of the Nigerian Government appointed the International Civil Aviation Organization (ICAO) as the Executing Agency responsible for carrying out all of its commitments during its programme of assistance.

The initial UNDP programme of assistance for the first phase came to an end on 31st December, 1974. Since that time, the Government of the Federal Republic of Nigeria has assumed full responsibility for the continued operation of the Training Centre. A Board of Governors appointed by the Government is charged with the responsibility for the organisation, administration and policy planning of the Training Centre. The Board is answerable to the Federal Minister of Transport and Aviation. The Principal of the Training Centre is responsible to the Board for the day to day administration of the Centre.

OBJECTIVES OF THE PROJECT

The long range objectives of the project is to provide the Civil Aviation industry as a whole on a continuing basis with the trained personnel who will be able to carry out their duties and ensure safe air and ground operations according to recognized international standards.

The immediate objectives are to provide Pilots, Aircraft Maintenance Engineers, Air Traffic Services and Communications personnel, Aeronautical Electronics and Telecommunications Technicians and Technologists, and other highly skilled manpower required by the Civil Aviation sector in Nigeria and all friendly African countries.

In the fulfilment of the above objectives, the Training Centre has, since 1966, given admission to about one thousand students for various Civil Aviation courses. Out of this number, over one hundred have so far been admitted from the following African countries: Ghana, Sudan, Somalia, Liberia, Ivory Coast, Mali, Sierra Leone, Cameroon, Niger, Kenya, Uganda, Tanzania, Rwanda, Sao Tome, Lesotho, Zambia, Malawi and Swaziland. Over seventy pilots and one hundred aircraft maintenance licenced engineers have so far been produced mainly for the national airline, the Nigeria Airways; over fifty air traffic controllers, over one hundred communications personnel, and well over one hundred aeronautical electronics and telecommunications technicians and technologiests have since been produced mainly for the Nigerian Civil Aviation Department. All the courses have been based, and will continue to be based on the International Civil Aviation Organization Training Manual Syllabi with emphasis placed on maintaining the minimym standards and recommended practices laid down in the various Annexes to the Convention on International Civil Aviation..

ORGANISATION AND STRUCTURE

The Training Centre is organised into four different Schools namely, Flying School, Air Traffic Services and Communications School, Aircraft Maintenance School and Aeronautical Electronics and Telecommunications (formerly, Radio) School.

All four Schools offer standard as well as specialised courses.

The Flying School offers a standard course in flight training for Commercial Pilot Licence with Instrument and Multi-Engine type ratings. It also offers the theoretical courses for the Airline

Transport Pilot Licence and also Jet Simulator conversion and refresher courses for graduate pilots and senior pilots for the airlines. Air Traffic Services/Communications School trains Air Traffic Controllers as well as Aeronautical Communications Officers. The School would soon introduce courses in Area/Airways Control and Air Traffic Control (Radar). The Aircraft Maintenance School trains Aircraft Maintenance Airframe and Engines - 'A' & 'C' - Licenced Engineers and personnel with 'X' Electrical and Instruments licensing qualifications. The Aeronautical Electronics & Telecommunications School trains Aeronautical Maintenance Technicians, and Telecommunications Technologists who are responsible for the maintenance of all Aeronautical Navigational Aids equipment including Very High Frequency Omni-Directional Range (VOR), Distant Measuring Equipment (DME), Instruments Landing System (ILS) and Air Traffic Control Radar euipment.. The levels of knowledge and skill for successful completion of all the standard courses and the specialised courses conform with the minimym standards and recommended practices outlined in Annex I - Personnel Licensing and other relevant Annexes to the Convention on International Civil Aviation. The Syllabi and course curriculae are based on the materials contained in the relevant ICAO Training Manuals and the specialised equipment manufacturers' manuals.

RECRUITMENT OF TRAINEES AND ENTRY QUALIFICATIONS

Most of the trainees are recruited from Nigeria while quite many come from other African countries mentioned earlier. In Nigeria, some of the trainees are recruited directly by the Training Centre while others are recruited by the various sponsoring bodies such as the Ministry of Civil Aviation, the Nigeria Airways and the Federal and State Scholarship Boards. Nigerian pilot students are

selected directly by the Centre through series of aptitude tests and interviews with the collaboration of the Test Development and Research Office (TEDRO) of the West African Examinations Council, Lagos. For any of the courses run at the Centre, the minimym qualifications is the West African School Certificate with at least credits in English Language, Mathematics and Physics or five passes at the General Certificate of Education Ordinary Level including the three subjects already mentioned, or the City & Guilds Intermediate (or equivalent) in the appropriate field of training. In addition, the would-be trainees must be medically fit. Professional pilot trainees and air traffic controllers would normally enter the Training Centre between the ages of 18 and 23 years. They must be medically fit in accordance with relevant ICAO medical standards for pilots and air traffic controllers.

THE FLYING SCHOOL

The Commercial Pilot Licence syllabus has been designed so as to satisfy the requirements of the International Civil Aviation Organization and the licensing requirements (presently based on the United Kingdom pattern) of the Civil Aviation Division of the Ministry of Civil Aviation.

The ground subjects taught include Navigation (General and Plotting), Flight Planning, Radio and Radio Aids, Aerodynamics, Aircraft Engines and Systems, Aircraft Performance, Aviation Meteorology, Aviation Law, Air Traffic Services and Communications including Radio Telephoney. Flight training consists of 200 hours on single engine aircraft (Cessna 150 and/or Cessna 172), 50 hours on twin-engine aircraft (Piper Aztec), 60 hours Instrument Flight Procedure training on Link Model 60 and GAT-I, and 50 hours Instrument Flight

training on CAT-2. The course length is 81 weeks and the present fee for the course is ₦14,000 (fourteen thousand Naira). Students are admitted twice a year, that is, in January and June/July of every year. Both theoretical and flight examinations are conducted during and/or at the end of the course. The theoretical examination for Commercial Pilot Licence and Instrument Rating, consisting o papers in Navigation, Flight Planning and Meteorology are at present set and marked by the United Kingdom Civil Aviation Authority (CAA) under an arrangement between the U. K. authority and the Civil Aviation Division of the Ministry of Civil Aviation.. Examination on Aviation Law, Aircraft Systems and Aircraft Performance are set and marked by the responsible examination bodies in the Ministry of Civil Aviation. The Ministry's Test Pilot conducts the flight tests for the Commercial Pilot Licence with Instrument Rating. A Student must pass the theoretical written examination as well as the flight test and the medical test before he is awarded the Commercial Pilot Licence with Instrument Rating.

Courses offered on the F28 simulator include Transition and basic jet handling for frsh pilots, of three weeks duration. Others are re-currency and check ride. The fee is ₦250 per hour (two hundred and fifty naira per hour) of flying time.

The Nigerian Civil Aviation Training Centre purchased an F28 Digital Flight Simulator with Six Axes Motion System and Novoview Visual System from Rediffusion Simulation Ltd; Crawley, United Kingdom through the Civil Aviation Purchasing Service (CAPS) of the International Civil Aviation Organisation in 1981. This equipment was the most sophisticated civil aviation training device so far brought into Nigeria. The installation of the Flight Simulator was carried out in 1981 with a lot of pains, changes in plans, high cost hired plants spending a lot of idle time and heavy cost of keeping the foreign labour..

The heavy losses in time and cash are thought to be highly attributable to lack of suitable management skill in planning the installation. Since a similar installation (Boeing 737 Flight Simulator) may soon be installed, a review of the installation is hereby done and the technique of network analysis applied in order to improve efficency, reduce delays and costs.

OBJECTIVE AND SCOPE OF STUDY

This project examines the installation proceedure of the F28 Flight Simulator in Zaria, Nigeria in order that

(i) A network diagram of the activities will be produced, identifying the critical path (s), time and cost.

(ii) Reduction of time and cost will be made

(iii) Suitable recommendations will be made for future installations.

THE FLIGHT SIMULATOR

Of the major inventions, the flight simulator may be regarded as a PRACTICAL joke, just as its history began. Just before the second world war, an American named Edward Link was seeking ways of pleasing his younger brother who was very keen on flying but had no money to finance his private flying. Link then decided to build a small wooden cabin in the shape of an aircraft cockpit and fitted it with home made items that looked like the controls of an aircraft. This mimic amused the young man who invited his friends to learn to fly in this "blue box" as it was named. Link's name suddenly jumped up the American Aviation Hall of fame when the US government, desperate to produce airforce pilots fast during the war against Hitler, discovered the blue box. The blue box was further developed by researchers to become more eff ctive, thus cutting down the actual airborned training. This story of success led to the commercialization of Link's idea that today produced some of the giants in the business; Singer-Link Company of USA whose net sales exceeded US $200m in 1975, Rediffusion Simulation Ltd of England (US $204m). CAE of Canada (US $121m)[1] Simulators have since been manufactured for civil, military, space flying machines as well as for power stations, automobiles, trains and air traffic control facilities.

The F28 Simulator consists of major assemblies that together make realistic flying possible within it. The largest single unit is the fuselarge which is made up of a large motion platform with dimensions approximately 4.5m by 6m. On the platform is mounted a glass fibre shell that forms the flight deck and instructor station together with on board electronics cabinets and the visual monitors.

The flight deck is an exact replica of the deck of Nigeria Airways F28 aircraft MK2000 with registration 5N-ANI, tabulation number SN11108 as defined in the Fokker-VFW Specification with Addendum. The flight simulator faithfully duplicates the performance and operational behaviour of the actual aircraft within the flight envelope as defined in the certification programme. The systems, together with the associated switches, controls, instruments, indicators, displays, lights, fuses, circuit breakers, etc are simulated according to approved data. The actual aircraft instrumentation, avionics and components have been used to the extent possible to simulate realistic representation of the actual aircraft.

The next major assembly is the support motion system. Six servo actuators anchored at the three tips of an equalateral triangle on the floor are jointed to the motion platform at three points by use of universal joints to provide realistic motion cues during all phases of flight. Associated with the motion actuators are three motion puups, hydraulic reservoir tank, motion electrics cabinet and the motion control cabinet.

Computing hardware together with associated interfacing electronics and power cabinets consitute another major assembly. In essence, there is a general purpose computer, the R2000A; the CAT A Linkage which interfaces the computer with the flight deck. A series of cabinets designated as BAY 08 contains the multitute of power supplies used throughout the complex. Another cabinet contain the static inventor which generates the 400HZ signal needed for syndro instruments. A micro computing system for monitoring pilot performance by the instructor known as the Modular Advanced Graphic

Generation System (MAGGS) all of the above utilise the simulator programme (software).

Visual simulation of airport scenery is achieved by the use of some special hardware called the Novoview SP 1 which processes stored data base and current software update from the host computer (R2000A). The hardware consists of a Texas Instrument model 980B minicomputer, the special Image Generator (SP 1), The ASR 733 Terminal, a model LP 2 Advanced Electronic Devices floppy disc unit, 4 units of series 1910 by Display Systems Inc. together with seperate power supplies.

Ancilliary equipments comprise fuselarge airconditioning unit wich is piped to the flight deck, a network of hydraulic pipes for motion and control loading, smoke generating unit (Smoke Genie) for simulating cockpit fire, oxygen system, purpose made boarding ramp and the motion oil cooling unit.

SIMULATION PROCESS

Flight Simulation Process

The entire flight simulation is built around a powerful software which has been generated for this particular aircraft, based on information provided by the lire aricraft manufacturers, Messrs Fokker-VFW of Holland. All of the data that were gathered during the various test flights of the particular aircraft (F28 MK 2000 SN 11108) are incorporated in the varuous computer programmes for the flight simulator. Thus, details of engines performance, electrics, airconditioning, pressurisation, flight, control feel,

environmental conditions, sound, instrument responses, safety limits, hydraulics, control effects geographical displacement on a global basis etc, are written as seperate computer programmes. A supervisory programme coordinates these varuous programmes. The R 2000A computer runs these programmes in accordance with the schedule dictated by the executive (supervisory) programme on a real time basis. By use of special interface electronics, the flight deck is made to interrupt the running programme in the computer. Thus, any pilot action from the flight deck is transmitted to the computer for evaluation. The result is immediately communicated back to the flight deck, resulting in a series of responses from the deck. This may be a control movement resulting in a change in aircraft attitude, engine sound, motion cur and instruments reading changes. The speed of response is such as would happen in the live aircraft. The feel will also be similar to that which would have been experienced in the live machine. Thus, to the pilot, he is actually flying that aircraft. To all to the realism of flight, a visual presentation is added.

Visual Simulation

Because most flights are above weather, visual presentation has been limited to a small range around the particular airport being simulated. Limitation is further imposed by cost of producing extensive scenery.

Visual similation derives from established data base and its management by the visual computer, thence the ultimate image presentation at the displays. The particular airport to be simulated is

described by the general night scenery of a 16 km square surrounding the airport runway. Thus, not all of the metropolis surrounding an airport may be shown. Data on the partern of lightings are mapped out, including the runway edge indicator lights (REILS), taxiway lights, approach light, traffic lights (option) etc. All of these are then converted into suitable data which can be used by the visual programme (NSPFLY) in the TI 980B computer. The storage medium for these data is the floppy disc. The NSPFLY programme running in the TI 980B computer demands some real time data from the flight simulation programme (about attitude, altitude, speed, geographical location etc of the aircraft) and combines this with the input from the data base to calculate the expected pilot eye view at any pint in time. The result of the computation is forwarded to the Image Generator which then determines what patterns are to be displayed to each of the two pilots both directly infront of them and on their side windows. It is to be noted that there may be slight differences in what the two pilots see, depending on the alttitude of the aircraft i.e. if the aircraft banks to the right, the pilot on the right sees both infront of him and his right side window whereas the pilot on the left only sees through his front window.

Motion Simulation

By the use of a synergistic support motion system, a six-degrees-of-freedom motion is achieved.

The motion somprises of the parameters of Heave, Lateral, Longitutional Pitch, Roll and Yaw movements. The support motion

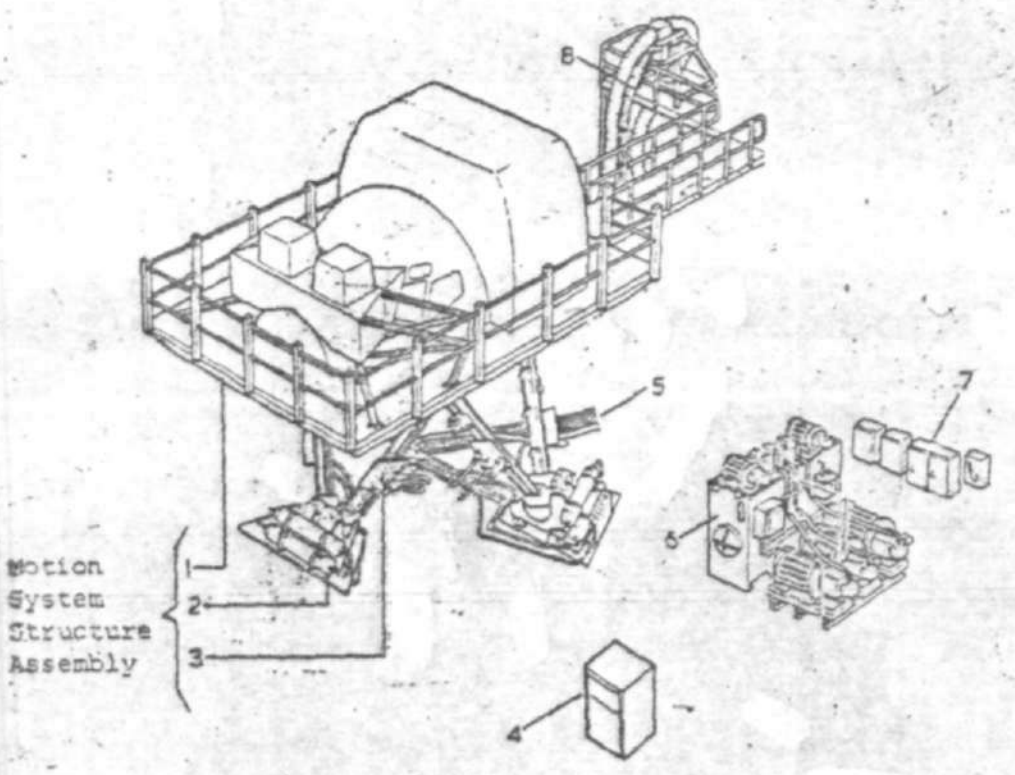
actuators are fed with hydraulic fluid under high pressure from three powerful pumps of the Hydraulic Power unit. The six pistons of these actuators are driven by the operation of special valves which are controlled by a computing device. The computing device obtains flight information from the flight simulator programme at regular intervals. The computing device will determine which pistons are to move to produce the necessary effect, thus signalling the pistons to respond through the valves. The computing device will also determine pressures, thus controlling when pumps should operate and how much pressure to deliver as the need may arise.

Scaling Limits

1.	Mach Number	-	0 to 0.85 Mach
2.	Altitude	-	-1000 to 40,000 feet with respect to mean sea level.
3.	Weight	-	up to 100,000 lbs.
4.	Centre of Gravity	-	10% beyond design limits
5.	Roll Angle	-	360 degrees (no limit).
6.	Pitch Angle	-	±90 degrees
7.	Heading Angle	-	360 degrees (no limit).
8.	Barometric Pressure	-	Normal to follow ICAO model. Instructor can vary sea level pressure 950 to 1060 mb.
9.	Surface Air Temperature (SAT)	-	40°c to $+55^{\circ}$c.
10.	Temperature Lapse Rate	-	-6°c/1000 ft. to $+1^{\circ}$c/1000ft.
11.	Profile	-	0-300 knots from any direction 0-360°

MOTION SYSTEM

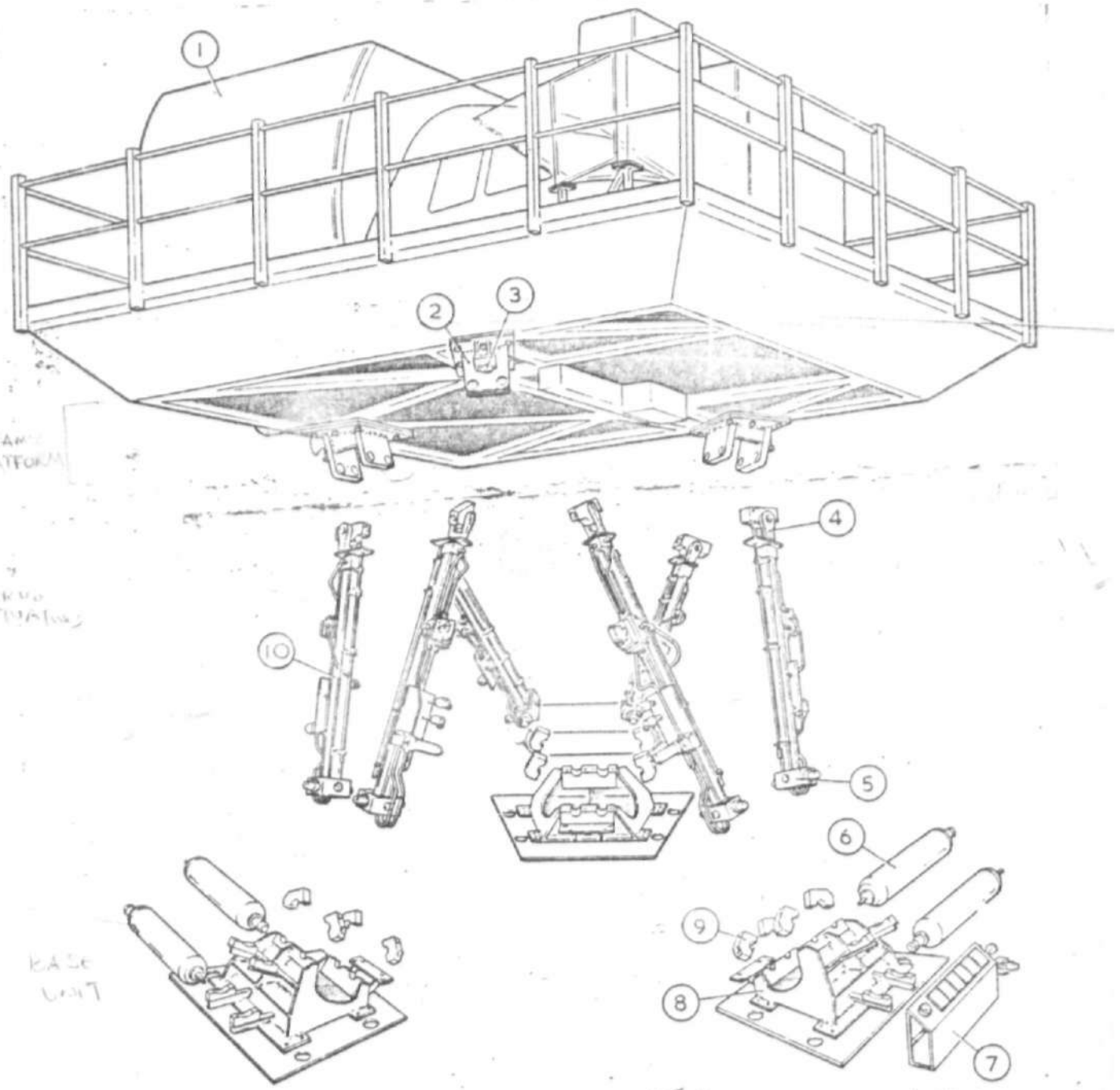
SIX DEGREES OF FREEDOM MOTION SYSTEM



MAJOR COMPONENTS OF SYSTEM

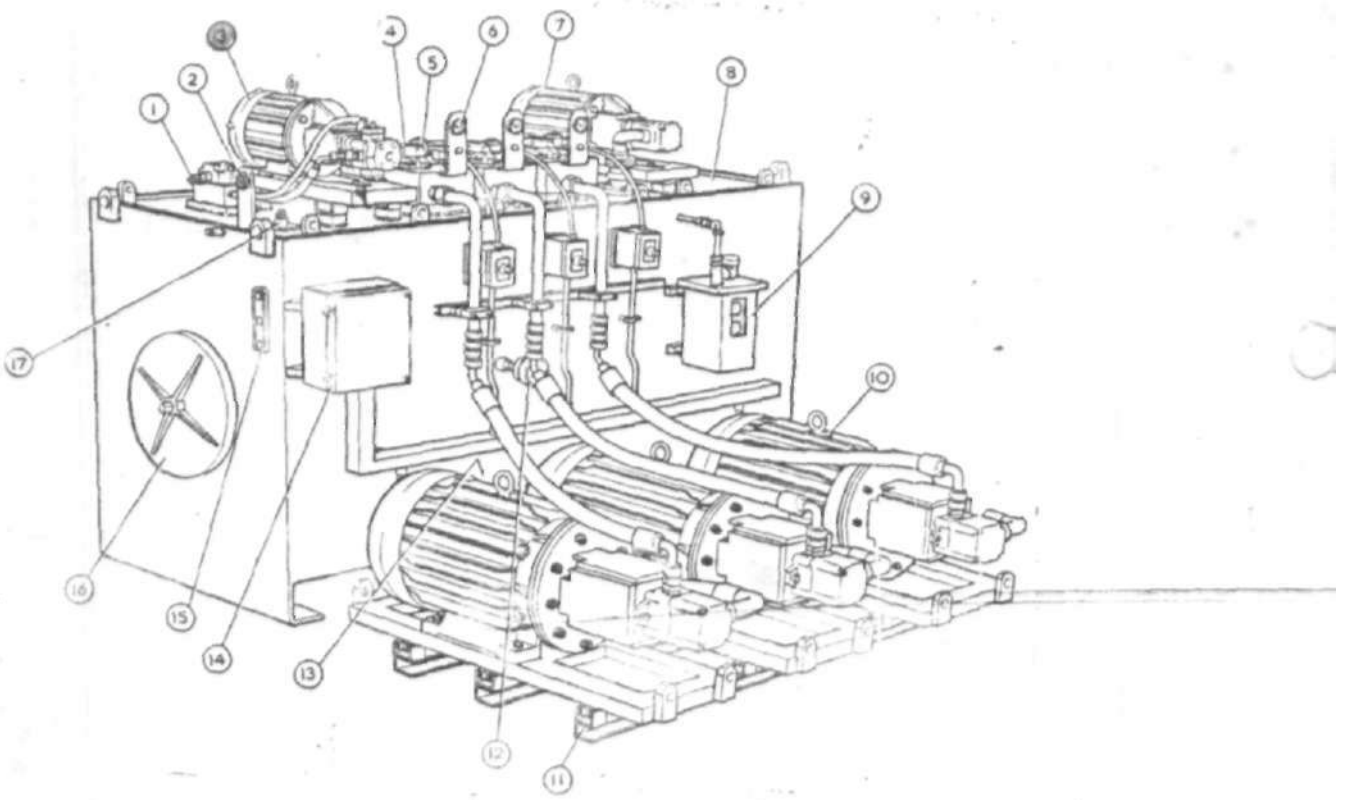
KEY TO FIGURE.

1. Fuselage Support Structure
2. Base assembly units
3. Servo actuator
4. Motion Control Cabinet
5. Hydraulic Pipes
6. Hydraulic Power Unit
7. Wall Mounted Enclosures
8. Cable Catenary



Item	Description	Item	Description
1	Fuselage Assembly	6	Hydraulic Accumulator
2	Upper Universal Joint Assembly	7	Gauge Panel Structure
3	Screw Jack Location	8	Base Assembly Units
4	Yoke End of Servo Actuator	9	Clamping Blocks
5	Universal Joint Members	10	Servo Actuator

Fig. 2 Exploded View of Motion System



Item	Description	Item	Description
1	Control Loading Pressure Relief Valve	9	Moisture Desiccator
2	Control Loading Pressure Gauge	10	Motion System Motor Pump Set
3	Control Loading Motor Pump Set	11	Anti-Vibration Mounts
4	Vented Pressure Relief Valve	12	Thermometer
5.	SEO3 Valve	13	Drain Valve (Behind Motors)
6	Motion System Pressure Gauge	14	Terminal Box
7	Cooling System Motor Pump Set	15	Sight Glass
8	Reservoir	16	Access Panel
		17	Oil Filler

Front View of Hydraulic Power Unit

LIMITATIONS OF THE STUDY

Being the first of such equipment installed so far in Nigeria, the estimate of timings of the activities is limited in accuracy, since no comparative gigures exist as such. However, since the writer was invloved in the installation, the estimates are considered realistic.

Due to contractural agreements between Nigerian Civil Aviation Training Centre and Rediffusion Simulation Ltd; there is some restriction on proprietory information which further mlimits writer's scope.

Because Nigerian Civil Aviation Training Centre, Zaria is a Federal Government Parastatal under the Federal Ministry of Transport and Aviation, labour renumeration is as the current government rate i.e. GL 01 - GL 16 (₦ per annum to ₦13,056 per annum) for civil servants. Hence local labour utilised during installation could only be costed on such figures, not on labour cost in an ad hoc situation. Similarly, the foreign labour cost was as per contract which was entered into 2 years before equipment delivery.

Since the installation was completed in July 1981, Nigeria had faced galloping inflation, social unrest, election truma and two military coup dê'tate. Conclusion based on this study would, therefore, be restrospective i.e. to apply to 1981 condition, though the method would be valid at the present time.

The study is limited to the point in time from when all the equipment have been off-loaded and uncrated.

DEFINITION AND EXPLANATION OF IMPORTANT TERMS

1.. Fuselage

This is the name given to the main round body of an aircraft, For a flight simulator, the portion so described is the shell (usually made of fibre glass) that houses the flight deck, the instructor bay and an-board electronics cabinets.

2. Actuator

The assembly of a two-way acting piston and rod in a long tubular housing. The piston action (extended or refracted) depends on the action of certain valves that will permit in-flow or out-flow of hydraulic fluid in the chambers on either side of the piston.

3. Hydraulic Power Unit

This unit consists of a large tank of hydraulic fluid, electric driven pumps and associated piping network that enable pressurized hydraulic fluid to be delivered to the motion actuators and also enable return flow when no demand is made..

4. Motion Control Cabinet (MCC)

The MCC is a free standing box which contains a micro processing system, visual displays, switches and power supplier needed to regulate the actions of the motion actuators and the Hydraulic Power Unit.

5. Novoview

This is the trade name for the computer Generated Image Hardware and associated software made by Rediffusion Simulation Inc. of Arlinhton, Texas USA.

6. Catenary Tower

The purpose made metal structure fitted to the mezzaine floor of the simulator bay to secure all electrical cables, airducts and control loading flexible hoses that link up with the fuselage so as to generate slack for the purpose of motion flight..

7. Universal Joint

A mechanical assembly which connects the motion act actuator to the motion platform so as to permit movement in different directions.

8. Fork Lift

A motorised land vehicle with two pointed bars (forks) in its front used to lift and carry heavy loads. The one used in this project has capacity for metric tonnes and can lift to a height of 3 metres.

9. Mobile Crane

A motorised land vehicle with extensible arm and hoisers which remains stationary when it lifts load and he arm rotates to deliver the load at any point within the radius of the arm-length. The mobile crane used for this project has a minimum rating (full arm extension) of 9 tonnes and maximum rating of 15 tons (full arm refraction).

10. Cavity Floor

If a part of a normal floor is recessed and now covered with slabs resting on purpose made supports such that the normal level is maintained and easy access to the cavity so created is possible, such floor is described as cavity floor. It is particularly useful where cabinets of electronics are linked by a mesh of wires . that can be passed under the surface (in the cavity) in order to reduce risk of damage to the cables and make for a tidy environment. The set up must be rated to stand all loads that may be imposed by the required equipments.

11. Diagnostics

A set of computer programmes that a run to point out errors in the computer or faults in the system..

12. Bay 07

This is the set of electronic cabinets that contain printed circutes which act as the interface or interpreter between the flight deck and the most computer R 2000A. This bay is also referred to as the LINKAGE.

13. Bay 08

All dc power supplies utilized by the flight deck and Bay 07 plus safety circuits as well as warning systems (smoke, power fail etc) are contained in this free standing cabinet.

14. ICAO

International Civil Aviation Organisation with Headquarters in Montreal, Canada. This is the world wide civil aviation regulating body..

15. Critical Path Method (C.P.M.) and Programme Evaluation and Review Technique (PERT)

CPM and PERT are management tools that serve as the science of using network techniques for the efficient utilisation of manpower, machinery and time in a project realisation.

16. Activity

This term refers to a job or a process among the processes in the whole project.

17. Event

Events are the points in time that define the beginnings and ends of activities. The "earliest event time" of each event is the total activity time that derives from going through the longest path to the event from the starting event.

18. Network

This relates to the activities and events that form a mesh when combined together.

19. Earliest Expected Time

The time at which the originating from an event can be started.

20. Latest Allowable Time

The latest time at which activities terminating at an event can be completed and still permit the entire project to be finished on schedule.[5]

21. Slack

In PERT, this is the time that can be spared. Slack can riewed as:-

(a) Total Slack: The time average obtainable in a project by which an activity may be delayed from its earliest start without affecting the completion time of the whole project.

(b) Free Slack: This represents the amount of time an activity may be delayed and yet not affect the earliest start of the succeeding activity.

22. Normal Time

It refers to the expected time of a project.

23. Normal Cost

The cost associated with finishing a project in the normal time.

RESEARCH METHODOLOGY

Having worked on Flight Trainers (Small Scale Simulators) and Digital Flight Simulators for a few years, my supervisor suggested that I should carry out a project in this area. Upon visiting the F28 simulator facility, my supervisor asked a few questions about the installation of the massive equipment. From the responses, it was clear that a review of the installation would be beneficial to the researcher and his employers.

The work is, therefore, not an attempt to prove any hypothesis through collection of data and analysis of same. Rather, the work is an analysis of a project already executed with a view to providing a better alternative way of executing the same project. Therefore, the project is based on the data collected from the installation of the flight simulator in 1981.

Contact was made with the management of the Nigerian Civil Aviation Training Centre, Zaria to grant permission for the study. Personal interviews with the participants in the installation project were granted. Access to the installation documents as proposed by the simulator manufacturers was also granted.

Data collected on the 4 year old project covered all the detailed activities of the installation; sequences of operation, timing of the various stages and the requirements of labour and skill, installation materials and difficulties encountered. The manufacturers programme of installation was a Gantt Chart.

After gaining a thorough understanding of the installation proceedure, the project was then broken down into smaller jobs (activities) and the management tool of Programme Evaluation and Review Technique (PERT) was applied to the project in order to determine if it would have been a better method of managing the installation. If the PERT method was found sufficiently advantageous, this would be recommended to the management of the Nigerian Civil Aviation Training Centre, Zaria for use during the installation of the proposed Boeing 737 Flight Simulator in the near future.

FOOTNOTES

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2. Spooner, A.M. (1973). Visual flight simulation experiencing continual improvement. ICAO BULLETIN 32 (4): 18-21.

3. Depigny J. H. (1984). The Civil Aircraft Simulator has become an irreplacable training tool. ICAO BULLETIN 39 (5): 18-20.

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5. Theirauf, R. J. and Klekamp, R.C: Decision Making Through Operations Research Second Ed. New York: John Wiley and Sons, Inc, 1975 pp 121-140.

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7. Fari, A. A. (1981). A study and Analysis of the maintenance of A Turbire Generator in the Power Plant of Kaduna Refinery Through the Technique of Network Analysis. Unpublished MBA Project Report. Ahmadu Bello University, Zaria, Nigeria.

CHAPTER TWO

GENERAL DESCRIPTION OF INSTALLATION REQUIREMENTS AND A REVIEW OF THE TECHNIQUE OF NETWORK

2.A. PROPOSED LAYOUT, FLOOR SPACE, POWER AND ENVIRONMENTAL REQUIREMENTS

The Simulator complex layout is made up of the following:-

(a) Simulator Bay

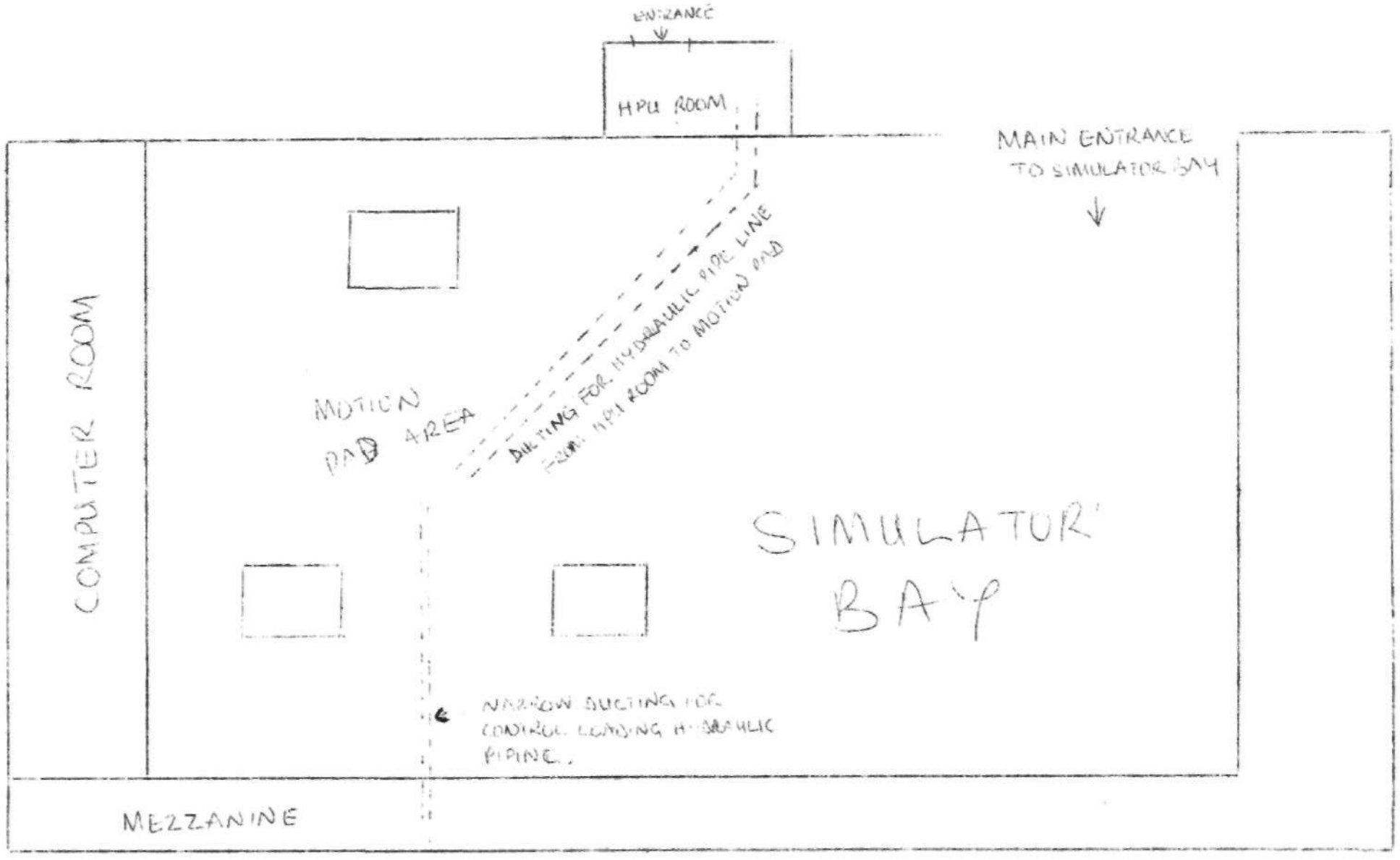
This large hall houses the simulated fuselage on six Axis Motion System with Novoview attachment, Motion Electrics Cabinet, and Fuselage Air conditioning Unit. Dimensions are 14 metres x 12 metres x 7.5 metres. This bay is provided with special access door 6 metres wide by 5 metres high. This is to enable the single largest component, the fuselage mounted on a motion platform. Immediately adjacent to this access door is created a free access space of not less than 7 metres square of concrete floor to support heavy vehicles delivering the crated loggages. See fig

(b) Computer Room

This 7 metre x 6 metre x 3 metre room, fitted with a cavity floor houses the R2000A computer, Bays 07 and 08. The static inventor (400H2 generator), Novoview image generator and computing hardware, the line printer, typewriter and disc drivers. The cavity floor is 230 mm high for cable laying and its panels (600mm square) are rated to stand 450 kg point load over 25 square mm with maximum deflection of 2mm in the centre of the panel.

(c) Hydraulic Power room

The Hydraulic Power Unit (HPU) is fitted in this room (6m x 6m x 3m) whose flooring requirement is sealed screed on concrete.


ENTRANCE
HPU ROOM
MAIN ENTRANCE
TO SIMULATOR BAY
MOTION
PAD AREA
DUCTING FOR HYDRAULIC PIPE LINE
FROM HPU ROOM TO MOTION PAD
COMPUTER ROOM
SIMULATOR
BAY
MEZZANINE

2.1 Power Requirement

Power supply is 3 phase 415 Volts ac with variation ±5% between phases and frequency of 50HZ in within ±%. Total requirement is 305 KVA maximum for 15 seconds and 180 KVA running, excluding supplies to airconditioning units, Lighting and other services.

2.2 Environmental Limits

		Temperature		Relative Humidity		Maximum Charge per Hour	
		Min	Max	Min	Max	°C	%RH
	Simulator Bay	18°C	26°C	20%	70%	2	3
C	Computer Room	18°C	26°C	20%	70%	2	3
	HPU	16°C	30%	20%	70%	3	5

Dust control should be achieved using air conditioning fillters of about 95% efficiency docon to 5 microns with humidity range 20% to 70%.

2.3 Lighting

Minimum maintained level (IES Code 1968) provides 200 Lux for simulator Bay, 600 Lux for computer room and 200 Lux for HPU room.

2.4 INSTALLATION REQUIREMENTS

Aspect of installation include positioning various equipment according to the schedule of the layout. Interconnecting cablles will have to be carried out while piping work has to be done for the hydraulic system. Air conditioning houses have to be

linked as appropriate. The various stages would require appropriate testing before linking with the other systems.

Movement of equipment around the various locations require the assistance of the forklift and mobile crane as applicable. Notably, the fuselage which weighs over 8 tonnes will be initi- initially lifted up and and purpose made wheels attached to it to enable easy entrance from the off loading point to the main simulator bay. This is achieved by the use of the mobile crane.

Both the mobile crane and the fork lift are hired plants which attract high hourly rates.

2.B NETWORK ANALYSIS

2.5 Background

The management of large construction projects, manufacturing, research and development has sought quicker and efficient ways to achieve goals so that cost and time are saved. Network analy or critical path method has been developed as a powerful tool to project monitoring and realization activities of any proj ct that may be "critical" are identified and projection can be made as to the e:pected finishing time of such project.

Thus, the allocation of resources such as labour and equipment can be made to minimise the total cost of the project. Should the case of a crash programme arise, optimum balance between the various costs and time involved may be worked out in order to reduce costs to minimum and generate profit.

CPM originated in 1957 through the joint cooperation of Remington Rand Division of Sperry Rand Corporation and E.I. du Pont de Nemours and Co. Insurance who used this to plan and control the maintenance of chemical plants. Subsequently, Du Pont applied the method to various engineering problems actual successes from the application of Network analysis includes

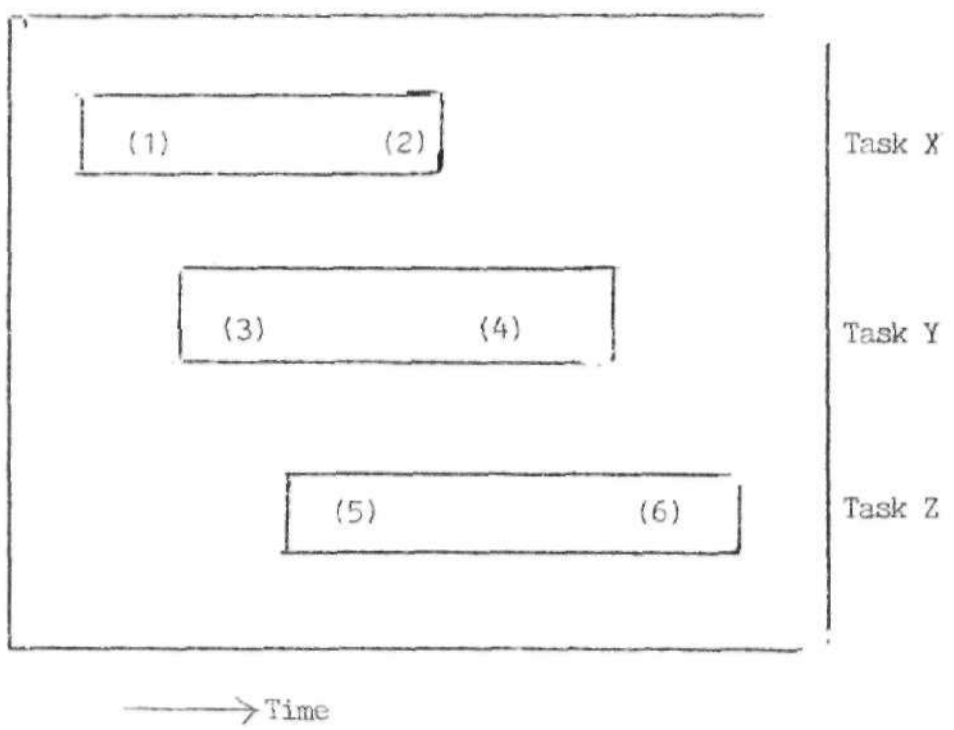
(a) Du Pont's saving of US $1million in a US $10 million project.

(b) By use of PERT the Polaris weapon system development saved 2 years over the estir a ed time.

(c) A 16% time saving and 27% in cash and labour in the maintenance programme of Shell's Petite-Conronne Refinery.

(d) A reduction of nearing 17% in a construction job (9 monts down to 7½ months) executed by Mauchley Associates.

The history of PERT may be associated with earlier work by GANTT who developed the Gantt milestone chart, a chart that represents the work to be done. It has a time scale accross the bottom of the chart that shows the specific tastes relative to the entire project. The Gantt chart, as illustrated in figure 2 depicts relationships among the circles contained in different tastes. A taste is represented by a rectangle and each of the circles represents the accomplishment of a specific phase of the total undertaking.



Gantt Milestone Chat

Fig. 2

Development of logical consideration of the various tasks resulted in due consideration to the performance of these various tasks. Could one task be performed independently or after the successful performance of some others. Thus, if such condition existed, then, one would have to wait for the prerequisite tasks to be performed before succeeding tasks could commense. This was the beginning of PERT. Suppose in fig. 2 above, tasks 1 and 2 would have to be performed before tasks 3 and 4 depended on the executor of 2 and 3 while 5 dependend on 3 leaving 6 as a function of the performance of 5 and 4, the outlook of the digram would now be as below in fig. 3.

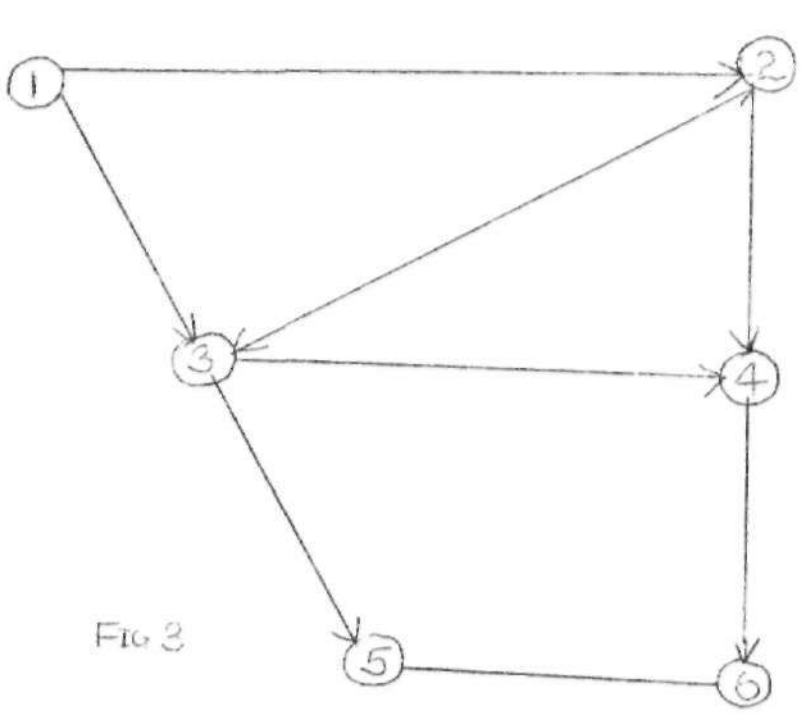


FIG 3

Subsequent development changed the diagram by indicating individual timing on the various arrows, rather than use a single time scale. Thus, the visual presentation is more informative as shown in fig. 4.

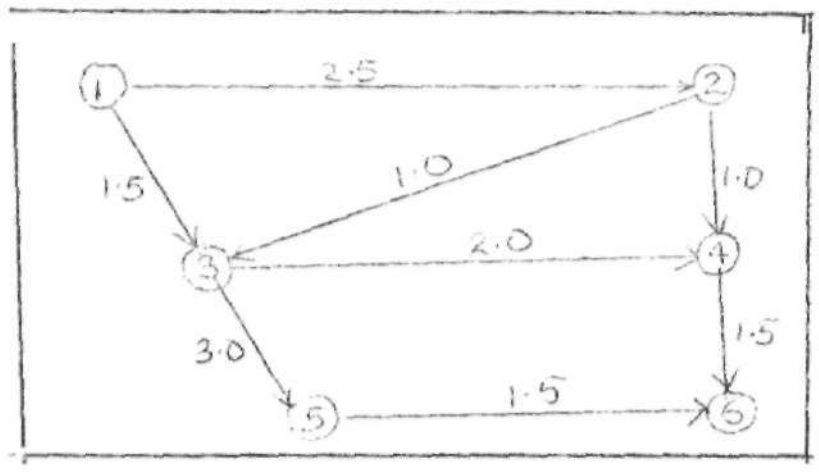


FIG 4

2.6 Proceedure

In order to apply the network technique, first, a network has to be prepared. Next, an analysis of the network will be made in order to be able to determine results and necessary recommendations.

2.7 Preparing the Network

In order to prepare the network, the following inputs are necessary:-

(i) Definition of the scope and purpose of the whole project.

(ii) Identifying individual tasks (called ACTIVITIES) which may be regarded as sub units or job executions that time and cost can be seperately assigned to

(iii) Determining the logical relationship between the activities in (ii) i.e. at what point in time can one activity or set of activities commense in relation to other activities.

(iv) Identifying the beginning and ending of such activities (referred to as EVENT)

(v) Determining for each activity time duration, labour and skill input required and any possible restrictions. Could such activities be shortened by increased cost or not etc.

2.8 Analysing the Network and Preparing Reports

The analysis of the network should point out

(i) Those activities that are critical to the project determination (completion time and costs)

(ii) Other details e.g. delay in starting some activities at no extra cost etc. Thus, the manager must be very concious of the time value of money and the various natures of the activities so as to be able to pay careful attention to those high cost ones.

2.9 Drawing the Network

As shown in fig. 5 below, every component task of the project, called ACTIVITY is indicated by an arrow, the tip and tail of which are denoted by a circle each. The label for the ACTIVITY is marked on the body of the arrow. The circles (usually numbered 1,2,3.....or 10,20,30,.....) are denote the start and end of the activity with which they are associated and they are termed EVENT. The sense of the arrow denotes the sense of the flow of the activity.

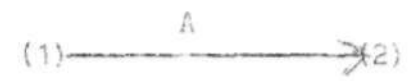


Fig. 5

The numbering of the events is ordered to show the flow of the logical sequence. These numbers also serve as nodes or addressable points of a computer model of the network is prepared.

A more complex interrelationship is shown in fig. 6 in which six activities (A,B,C,D,E AND F) comprix the project.

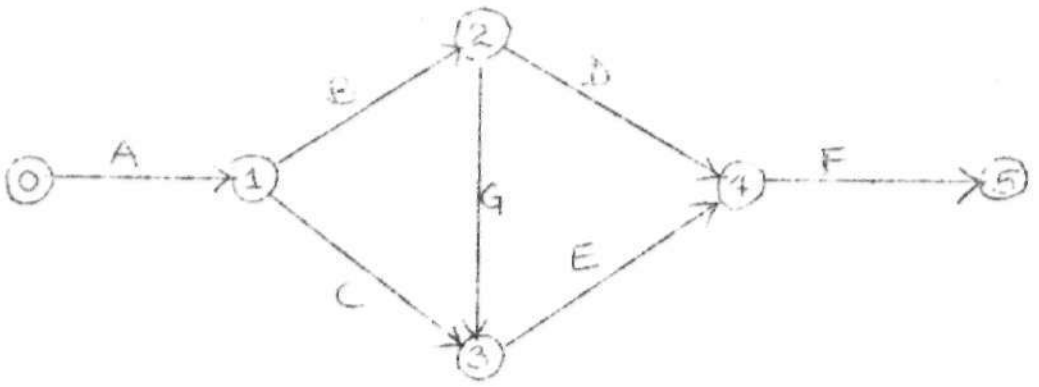


FIG-6

PERT Network

Situation arise in which the logic may appear confusing. As depicted in fig. 7, without the use of the "Dummy Arrow" it would be difficult to sketch the relationship that exists here, namely:- Activity C is preceeded by Activity A and B. Whereas activity D is preceeded by activity B, activity D however, has no relationship with activity A. Thus, to lump activities C and D on a single node would lead to a wrong assumption of the relationship between A and D.

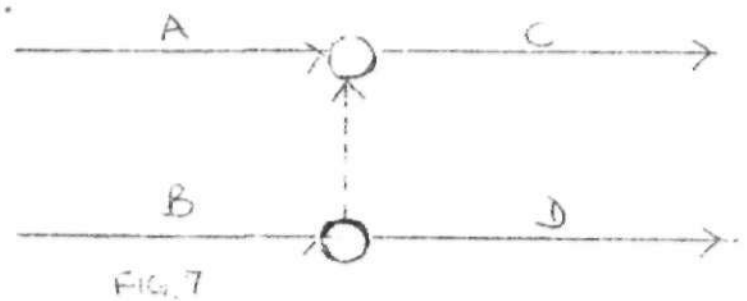


FIG. 7

Example of Dummy Arrow ----------->

2.10 Analysing the Network

Three major elements are of interest in analysing the network. The analyst looks out for the following:-

(1) The element of Time which determines schedules and slacks that may have been generated.

(2) The element of Resources by which the formulation of the distribution of trades, equipment etc needed for the various aspects.

(3) Cost element is used to place cash value on the whole project.

2.10.1 Time

Consideration of Time element in a network analysis reveals potential and risks in the project such as:-

(a) The minimum time in which the project can be completed (on the basis of the estimated times of the various constituent activities)

(b) The set of those activities which are to be considered critical i.e. which must be completed on time if the target completion date is to be met.

(c) A set of all other activities through whose relationship slacks may be generated; thus pointing out sources of savings.

All of the above when put together will help the analyst utilize a systematic proceedure which will thus identify the activities having potential for shortening the over all duration of the project.

2.10.2 Resources

So as the economic phenomenon of scarce resources applies, projects will like other human activities be subject to the same need of balanced resource allocation. It nearly becomes a game of "hide and seek" as the competing activities will have to be carefully considered for resource allocation. The analyst is faced with difficult decision making as he may have to trade time for some critical activities. The sum total will include consideration of labour (tradesmen, semi-skilled and unskilled, plus high skills e.g. computer engineers) as well as capital equipment such as cranes, bulldozers, earth moving machines and other plants.

The proceedure is to

(a) Make an analysis of the requirements for each type of resource according to various a ctivities, project by project, period by period.

(b) Obtain data for each particular resource the total requirements for each period, assumming that each activity is started at earliest time possible.

(c) Balance the resource requirements either by delaying the least critical activities or charging the resource available.

2.10.3 Cost

Cost analysis in a network is used to reduce to the minimum possible the cost of the entire project. This cost represents the sum of the direct and indirect costs. Direct cost derives from cost of labour, material and expenses needed to execute the whole project. Expenses that do not go directly to the project but are as a result of the project (loss of time, etc) are referred to as indirect cost. The manager seeking to profit by this analysis will require to follow the proceedure below:-

(a) Estimate the normal time and associated normal cost of the most critical activities.

(b) Determine if such activities in a can be reduced in time dimension and obtain costs of such time saving. This may be a result of doing overtime or employing more labour or machinery in order to reduce time to minimum.

(c) From data gathered as a result of steps a and b, tabulate the direct costs for progressively shorter completion time. These costs are computed by reducing the time taken for those critical activities which cost least to reduce. This proceedure may change the critical path are or more times.

(d) Obtain a similar table for indirect costs for each considered completion time, since indirect cost may likely be affected by the time taken to complete the project.

(e) Add the direct and indirect cost and determine the best time and cost combination.

As a result of steps a through e above, a graphical representation of cost relationship with time may be depicted as in fig.8 below.

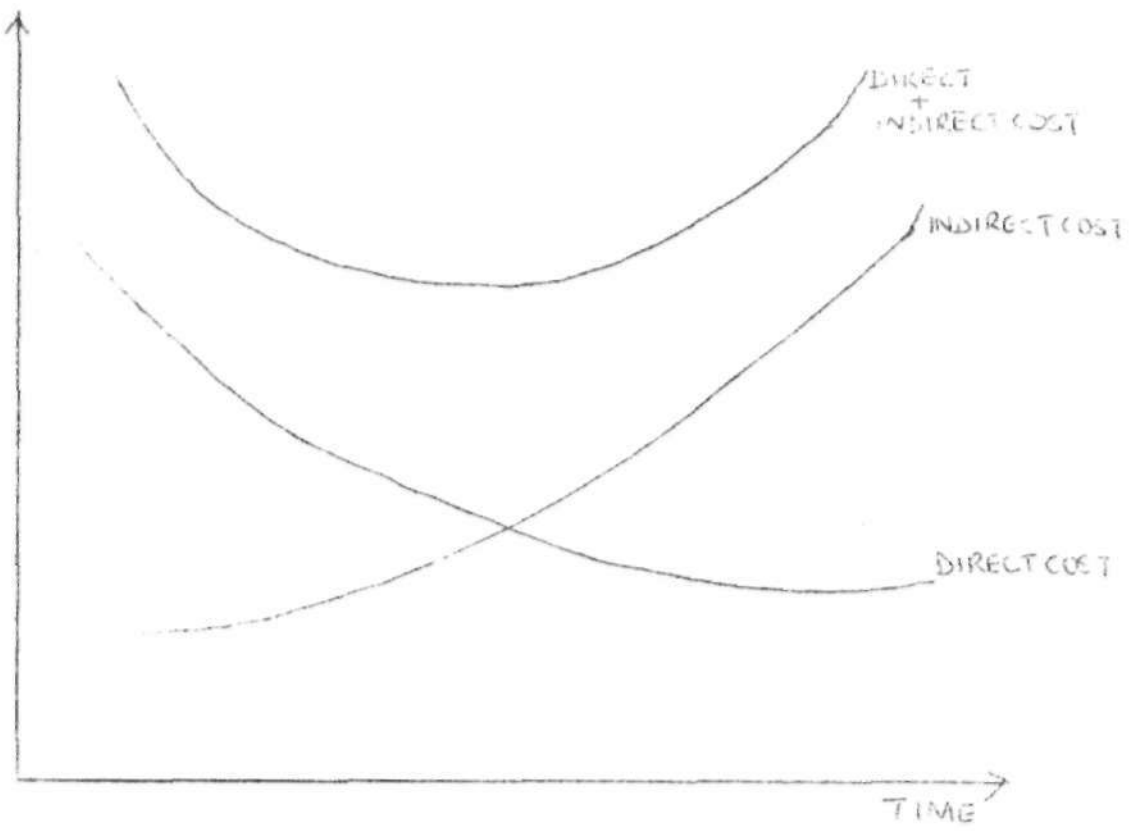


Fig. 8

Cost versus time.

2.10.4 Setbacks in PERT

1.. Because of the high dependence of the PERT technique on accurate time information, without due regard to external environmental changes, the extent of its accuracy is no better than that for gathering the information on timing.

2.. PERT ignores some factors of cost, capital and manpower availability.

2.11. WHY THE NEED FOR INSTALLATION PLANNING

In the contemporary Nigeria, such equipment as the Flight Simulator is of such high technology and high cost in hard currency that small mistakes may result in high costs and damages that may not be easily made good. The entire equipment, because of share size bigger than aircraft cargo door, had to be shipped by sea from the United Kingdom to Nigeria via the Lagos Port. Thereafter, heavy duty trucks conveyed the cargoes to Zaria where installation was to take place. Considering the various inputs of the installation exercise, the need to plan the installation may be adduced as follows:

(a) Personnel

A team of engineers and technicians had to be dispatched from the factory of the manufacturers of the Flight Simulator, Messrs Rediffusia Simulation Ltd, U.K., to Zaria, Nigeria, to carry out the installation, together with their Nigerian counterparts. Hotel accommodation, transpot expenses, communication and medical services were all paid for by the Nigerian Civil Aviation Training Cent4e, Zaria, the buyers, for as long as the installation took.

(b) Equipment

So long as the equipment remained uninstalled, it stood greater risk of damage through rust, especially that the crate might have gathered moisture while on the high seas. There was the increased risk of severe weather changes

(UK to Lagos and then Zaria). Pilfirage could not be ruled out, From the moment the equipment was installed, it had a ready market for its operations that guaranteed a daily turnover of at least ₦2,000 (two thousand naira) from the moment the installation was completed, the risk to equipment would be hightly reduced as it would be within a controlled environment (Humidity and temperature controlled by the use of powerful air conditioning units).

(c) Plants and Machinery to be hired

The installation involved the use of certain plants and machinery (eg. mobile crane, power pipe bender etc). The hourly rates for these equipment are high and some of them were not obtainable nearly, eg. Boeing 737 aircraft jacks had to be imported from Lagos while one mobile crane came from Kaduna. Lack of planning would result in untimely requests which will thus make the organisation pay heavily for idle time of such equipment or even cause so much delay of other activities, hence time and money loss.

(d) Contractual Obligations

From the contract point of view, buyer was expected to provide certain facilities to enable installation in reasonable time. At the end of installation, buyer would then be in position to sign the qualifying certificate upon which stage payment to the vendors is based. Thus, the UK bank in which a letter of credit was opened for

the purpose of such payments could only honour qualifying certificates duly signed by appointed signatories. If delay was caused by the buyer such that there was delay in payment, then the delay would be converted into cash at the current interest rate (about 17½%) in England at that time. Since heavy cash outlay (reasonable fraction of one million pounds British Sterling) was involved in each stage payment, interest charges made as a result of delay would run into tens of thousands of pounds due from the buyers.

FOOTNOTES

1. Rediffusion Ltd., UK (1978) Facility Desing Criteria. Document contained in the Tender for F 28 Simulator.

2. Moore, P.G., Basic Operational Research London :Pitman Publishing Ltd., 2nd Ed. pp18 - 28

3. Carsn, B.G., Bolz A.H., Young, H.H. Production Handbook New York : John Wiley and Sons 3rd Ed. P 10.52

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CHAPTER THREE

ANALYSIS AND INTERPRETATION OF DATA AND RECOMMENDATIONS

How The Installation was carried out in 1981

A detailed programme of installation contained in a handbook titled Standard Installation Proceedures was prepared by the Simulator manufacturers, Rediffusion Simulator Ltd., U. K. The layout of the installation allowed a total of seven weeks or forty-nine days for project execution. In order to execute the proposed plan, of course, it was necessary that all of the services of other machinery and plants were available with zero time request i.e. instantaneously. The installation lacked merit as it only prescribed achievement by dates rather than what to do and how best to get the job done (see fig 10). Thus, the Site Manager was left to use his discretion in the installation exercise.

One of the wasteful outcomes of the unplanned installation was the hiring of a mobile crane to lift a piece of equipment three times instead of once simply because the other items had not been positioned properly to make enough room for crane operation. Secondly, aircraft jacks were hired from Lagos, flown in as a chartered flight, the arrival of which was too early for that operation. Because of the tight scedule of the usage of the jacks in Lagos, another chartered flight had to return the jacks to Lagos (after the two day contract) only for a fresh request to be made a week later when the jacks were actually utilized for a period of only eighteen hours. The result was a clear loss to the tune of the charter fee and the hiring costs incurred. In addition, the loss of time on the project execution was at least four days due to the non-availability of the jacks when they were actually needed. This point in time occured three days after the jacks were returned to Lagos following the first

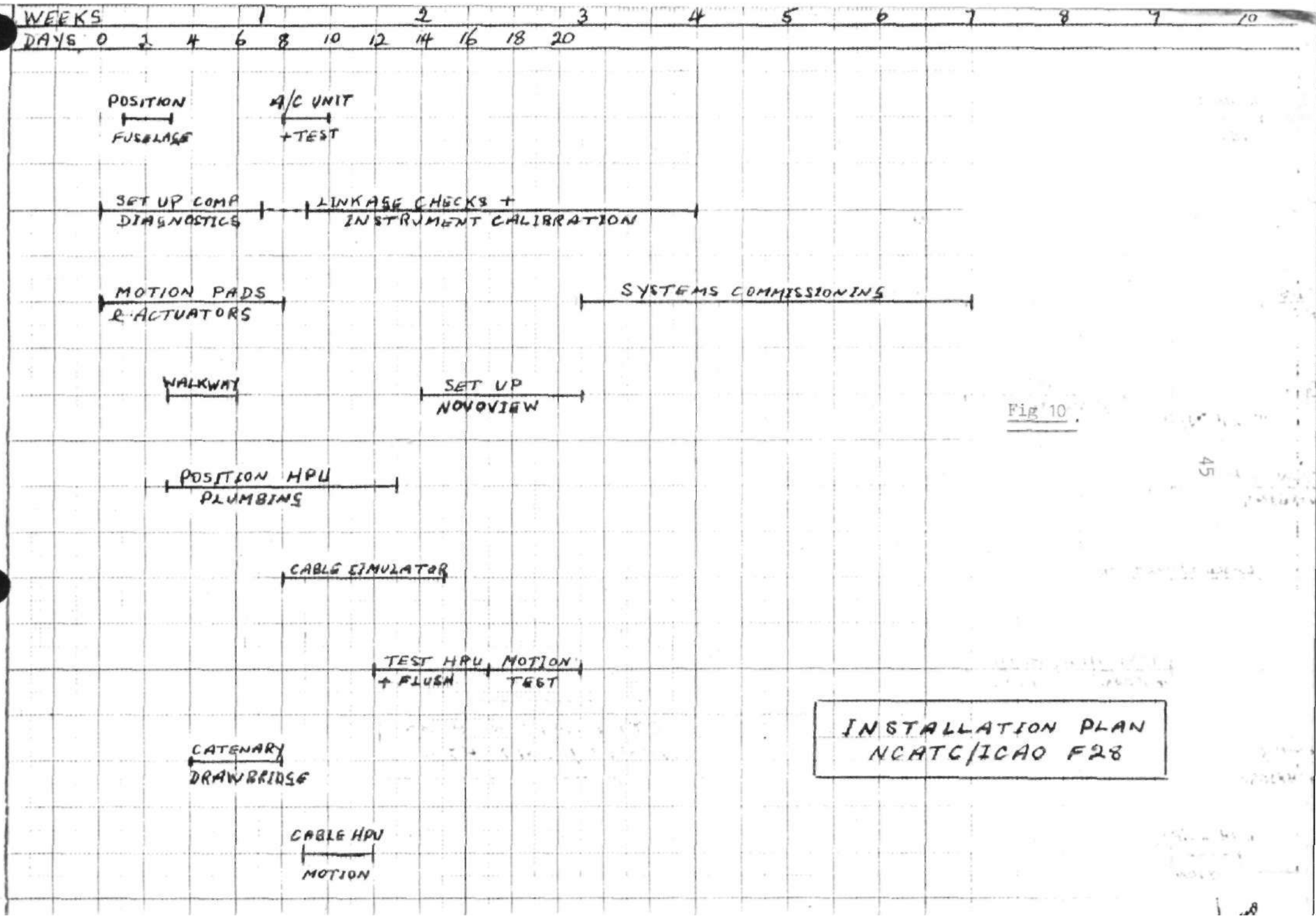

WEEKS 1 2 3 4 5 6 7 8 9 10
DAYS 0 2 4 6 8 10 12 14 16 18 20
POSITION FUSELAGE
A/C UNIT +TEST
SET UP COMA DIAGNOSTICS
LINKAGE CHECKS + INSTRUMENT CALIBRATION
MOTION PADS & ACTUATORS
SYSTEMS COMMISSIONING
WALKWAY
SET UP NOVOVIEW
POSITION HPU PLUMBING
CABLE EMULATOR
TEST HPU + FLUSH
MOTION TEST
CATENARY DRAWBRIDGE
CABLE HPU MOTION
INSTALLATION PLAN
NCATC/ICAO F28

Fig 10.

arrival.

One observation made is that the various groups (e.g. (e.g. computer and electronics commissioning groups, cable installation group etc) worked virtually independently and it was only by accident that one group stopped work to give the others room to do theirs rather than to a schedule that would assure maximum utilisation of the available manpower. Thus, there was high idle time.

A major setback was the lack of full utilization of the Rediffusion trained Nigerian engineers during the installation.. For fear of damage or incompetence or some apparent reasons (company policy, workers union requirement etc) a lot of the jobs that could have been carried out by the Nigerian engineers had to wait for the attention of the Rediffusion engineers and technicians. In the opinion of the writer, even simple jobs as positioning of the cabinets or others without power on were left to the high cost labour of the foreign technicians at a cost that would even be higher than the risk cost.

Fig 10 shows a Gantt Chart of the installation plan. All the thirteen broad tasks of the Gantt Chart are reviewed below with an indication of their relationships to the proposed PERT Table 2.

	GANTT TASK	PERIOD (DAYS) FROM DAY	TO DAY	TIME DAYS	RELATED PERT ACTIVITIES AND REMARKS
1	Cable HPC	7	12	5	Activity K
2	Cable Simulator	8	15	7	Activity M
3	A/C & Test	8	10	2	Activity F
4	Waldway	3	6	3	Activity T

TABLE 2

	GANTT TASK	PERIOD (DAYS) FROM DAY	TO DAY	TIME DAYS	RELATED PERT ACTIVITIES AND REMARKS
5	Position Fuselage	1	3	2	The actual positioning is dependent on positioning of all items in computer room, Fuselage a/c unit, motion pads.
6	Position Miscellaneous Equipment	0	4	4	This is assumed to include Interconnecting cable laying and electrical connections.
7	Motion Pads and Actuators			8	Four activities are involved namely Installation of motion Pads, connecting the Lower joints of Actuators, Raising of the Fuselage and connecting of the Upper joints of the Actuators to the Universal joints of the Fuselage.
8	Set up Computer Diagnostics	0	5	5	This strictly follows Task 2
9	Catenary and Drawbridge	4	8	4	These are two independent activities. The catenary tower could be mounted in parallel with the computer Room items while the Drawbridge cannot be fitted correctly unless the fuselage is resting on its support six axis motion-system (SAMS) with all electrical connection fully tested.

	GANTT TASK	PERIOD (DAYS) FROM DAY	TO DAY	TIME DAYS	RELATED PERT ACTIVITIES AND REMARKS
10	Position HPU and Plumbing	3	13	10	The location of the HPU Room is such that access to it is unobstructed by all other activities, being well located outside of the main Simulator bays and the Computer room. Hence this may be treated as a parallel activity. Only the plumbing between the HPU Room and the Simulator Bay can be affected by other activities. Thus, the plumbing can be started from the HPU Room and progress towards the Simulator Bay.
11	Novoview set up	14	21	7	The Novoview system set up depends strictly on the positioning of the fuselage and completion of the Computer Room diagnostics. There is a specialised group that works separately on this visual system, so their services depend on the above two activities.
12	Test HPU and Flush	12	17	5	In order to carry out this task, the activities requiring completion are the wiring of the motion system, connecting of the actuators to the motion pads.

	GANTT TASK	PERIOD (DAYS) FROM DAY	TO DAY	TIME DAYS	RELATED PERT ACTIVITIES AND REMARKS
13	System commissioning	21	49	28	This task includes activities N and J. Hence, the actual period is less than the Gantt prediction.

Preparation of the PERT Network.

In order to produce the PERT Network, it is necessary to determine the interrelationships of the various activities of the project and produce the table to indicate the time scale. This gives a picture of what activities have to be accomplished before some others or those that can be accomplished independently (parallel activities). The installation times of the major assemblies as per Rediffusion Installation Plan are used to produce Table 2 below. The labour input data are from records by NCATC.

Table 3 gives the breakdown of the various activities as proposed in this work, with data based on records and the generated column showing the possible input by the Nigerian engineers. The purpose of this table is to provide date for a "crash" programme i.e. in the event that the management insists on the very minimum foreign labour input and the shortest time, then more responsibilities would be transferred to the Nigerian counterparts, based on the knowledge of their training and familiarity with equipment handling. Therefore, the jobs requiring deep knowledge of the manufacturering or set up proceedure will then be the total responsibility of the Rediffusion engineers assisted by the Nigerians.

TABLE 2

The activities and normal time estimate along with the precedence relationships shown below.

(CR) = Computer Room (SB) = Simulator Bay (HR) = Hydraulic Power Unit Room. Time = days.

These times were extracted from the installation.

ACTIVITY	DESCRIPTION OF WORK	LOCATION	NORMAL TIME	IMMEDIATE PREDECESSOR
A	Uncrate all items outside	-	-	-
B	Position HPU	(HR)	1	A
C	Set up Bays 07 & 08, R2000A Computer, Static Inverter, Novoview Cabinet and Peripherals	(CR)	3	A
D	Plumbing of Hydraulic lines for Motion and control loading starting from HPU Room to Simulator Bay	(HR) (SB)	6	B
E	Installation of Catenary Tower	(SB)	1	A
F	Positioning of Fuselage Air conditioning Unit. Electrical connections and Preparation of Air Ducting pipes	(SB)	2	A
G	Cabling of interconnections between the Computer and interfaces	(CR)	4	C
H	Securing Motion Pads to the floor Botts and mounting of Hydraulic accumulators	(SB)	3	C

ACTIVITY	DESCRIPTION OF WORK	LOCATION	NORMAL TIME	IMMEDIATE PREDECESSOR
I	Wheel in Fuselage and locate over the motion Pad	(SB)	2	E, H
J	Powering up of computing and peripheral items. Setting up of Diagnostics and systems performance assurance Tests	(CR)	5	G
K	Wiring of the motion Electrics cabinets, electrical tests and cabling of the HPU to the Simulator Bay via Hydraulic/Cable ducts	(HR) (SB)	4	D
L	Covering of Ducts linking Hydraulic Room and Simulator Bay	(HR) (SB)	1	K
M	Cabling of Fuselage to the interface units in the Computer room via the catenary tower and cable raceway	(SB) (CR)	3	I,
N	Powering up flight deck and Instruments and systems calibration	(CR) (SB)	7	F, J, M
O	Novoview visual system setup and alignment.	(CR, SB)	7	F, J, M
P	Connecting up of motion actuators (60ff) to the motion Pads		2	I
Q	Charge up the Hydraulic HPU Test and accumulator baloons with Nitrogen (900psi)		2	L

ACTIVITY	DESCRIPTION OF WORK	LOCATION	NORMAL TIME	IMMEDIATE PREDECESSOR
R	Flushing of the motion system by running the dydraulic fluid through entire pipes and actuators and control loading network	(SB)(HR)	(3)	P, Q
S	Test Flight without motion (only control loading is utilized)		16	T N, O, T.
T	Walkway		3	I
U	Raising Dyramic motion Platform to enable connection of actuators		1	T N, O, T.
V	Connect upper end of actuators to the motion Platform universal joints. Lower motion Platform on to the support actuators (SAMS).		2	U
W	Setting up of the Drawbridge	(SB)	2	V
X	Motion Test	(SB)	4	R, S,V
Y	Clear all surrounding and remove crane, forklift and a/c jacks from the building	(SB)	1	W, X
Z	Integrated Flight Test (systems, visual and motion)	(CR, SB, (HR)	2	X W
Z1	Seal entrance to the building	(SB)	2	Y
Z2	Finish		0	Z, Z1

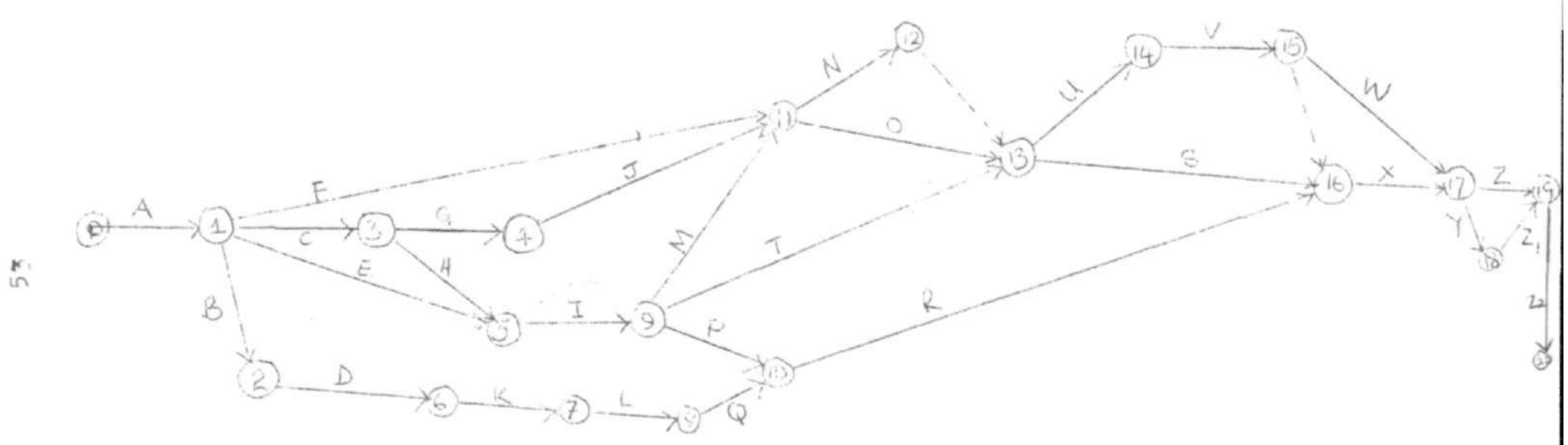


FIG. 11
PERT NETWORK FOR THE INSTALATION
OF A DIGITAL FLIGHT SIMULATOR
AT THE NCATC ZARIA,

TABLE 3

Labour rates

Nigerian Engineer (GL. 10)= ₦15.78 per day per person.

Rediffusion Engineer = ₦70.00 per day per person.

Labourers (GL. 01, 02) = ₦4.17 per day per person.

Nigerian Engineer in the table implies a complete substitution for the Rediffusion Engineer or partial.

WORK ITEM	REDIFFUSION PERSONNEL ENGINEER	TECHNICIAN	NIGERIAN ENGINEER	NIGERIAN LABOURERS	TOTAL DAYS
Position HPU			1	6	1
Set up Bays 07, 08, R2000A Computer, Static Inventer, Novoview cabinet and Peripherals			2	8	3
Plumbing of Hydraulic lines for motion and control loading starting from HPU Room to Simulator Bay	1		1	4	6
Installation of catenary Tower Positioning of Fuselage air conditioning unit, electrical connections and and preparation of air ducting pipes			1	2	1
			1	2	2

WORK ITEM	REDIFFUSION PERSONNEL ENGINEER	TECHNICIAN	NIGERIAN ENGINEER	NIGERIAN LABOURERS	TOTAL DAYS
Cabling of inter-connections between the computer and Interfaces	1		2	2	4
Securing motion Pads to floor Bolts and mounting of Hydraulic accumulators		1	1	4	2
Wheel in fuselage and locate over motion Pad	1	1	2	10	1
Powering up of computing and peripheral devices. Setting up of Diagnostics and systems performance assurance tests	2	2	2		5
Wiring of the motion electrics cabinets, electrical tests and cabling of the HPU to the Simulator bay via ducts		1	1	2	2
Covering of ducts linking Hydraulic room and Simulator Bay			1	4	1
Cabling of fuselage to the interface units in the Computer room via the catenary tower and cable raceway	2	1	2	4	2

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WORK ITEM	REDIFFUSION PERSONNEL ENGINEER	TECHNICIAN	NIGERIAN ENGINEER	NIGERIAN LABOURERS	TOTAL DAYS
Powering up of the flight deck, instruments checks and systems calibration.	2		2		5
Novoview visual system set up and alignment	2		2		4
Connecting up of motion actuators (6 off) to the motion Pads		2	2	4	1
Flushing of the motion system	1		1		3
HPU Test and charge up the Hydraulic accumulator baloons with Nitrogen (900psI)		1	1	2	1
Test flight and systems commissioning	2		2		16
Install walkway		1	1	4	2
Raise Dynamic pa platform to enable connection of the actuators	1		1	6	1
Connect motion actuators and lower fuselage unto the support SAMS		2	2	4	1

WORK ITEM	REDIFFUSION PERSONNEL ENGINEER	REDIFFUSION PERSONNEL TECHNICIAN	NIGERIAN ENGINEER	NIGERIAN LABOURERS	TOTAL DAYS
Setting up of the Drawbridge	1		1	3	1
Motion Test	1		1		4
Clear surrounding and remove unwanted machines			0	6	1
Seal entrance			1	6	1
Integrated flight test	2		2		2

From the network of the project, the following eighty one routes can be followed viz:-

	Days
A - F - N - U - V - W - Z - Z2	16
A - F - N - U - V - Y - Z - Z2	16
A - F - N - U - V - W - Y - Z - Z_2	17
A - F - N - U - V - X - Y - Z - Z_2	16
A - F - O - U - V - W - Y - Z - Z_2	17
A - F - O - U - V - X - Y - Z_1 - Z_2	16
A - F - O - S - X - Y - Z_1 - Z_2	17
A - F - O - S - X - Z - Z_2	19
A - C - G - J - O - U - V - W - Y - Z_1 - Z_2	32
A - C - G - J - O - U - V - W - Z - Z_2	31
A - C - G - J - O - U - V - X - Y - Z_1 - Z_2	27
A - C - G - J - O - U - V - Y - Z - Z_2	26
A - C - G - J - O - S - V - Y - Z - Z_2	29
A - C - G - J - N - U - V - W - Y - Z_1 - Z_2	28
A - C - G - J - N - U - V - W - Z - Z_2	26
A - C - G - J - N - U - V - X - Z - Z_2	28

A - c - G - J - N - U - V - X - Y - Z - Z_2 29

A - C - G - J - N - S - X - Y - Z_1 - Z_2 42

A - C - G - J - N - S - X - Z - Z_2 41

A - C - G - J - O - S - V - U - Z_1 - Z_2 42

A - C - G - J - O - S - X - Z - Z_2 41

A - C - H - I - M - O - U - V - W - Y - Z_1 - Z_2 26

A - C - H - I - M - O - U - V - W - Z - Z_2 25

A - C - H - I - M - O - U - V - X - Y - Z - Z_2 28

A - C - H - I - M - O - U - V - X - Z - Z_2 27

A - C - H - I - M - O - S - X - Y - Z - Z_2 40

A - C - H - I - M - O - S - V - Z - Z_2 40

A - C - H - I - N - B - U - V - W - Y - Z_1 - Z_2 26

A - C - H - I - M - N - U - V - W - Z - Z_2 25

A - C - H - I - M - N - U - V - X - Y - Z 1 - Z_2 28

A - C - H - I - M - N - U - V - X - Z - Z_2 27

A - C - H - I - M - N - S - X - Y - Z_1 - Z_2 41

A - C - H - I - M - N - S - X - Z - Z_2 40

A - C - H - I - T - U - V - W - Y - Z_1 - Z_2 19

A - C - H - I - T - U - V - W - Z - Z_2 18

A - C - H - I - T - X - Y - Z - Z_2 19

A - C - H - I - T - U - X - Z - Z_2 18

A - C - H - I - T - S - X - Y - Z_1 - Z_2 34

A - C - H - I - T - S - X - Z - Z_2 33

A - C - H - I - P - U - V - W - Y - Z_1 - Z_2 18

A - C - H - I - P - U - V - W - Z - Z_2 17

A - C - H - I - P - U - V - X - Y - Z - Z_2 20

A - C - H - I - P - U - V - X - Z - Z_2 19

A - C - H - I - P - S - X - Y - Z_1 - Z_2 33

A - C - H - I - P - S - Y - Z - Z_2 32

A - C h- H - I - P - R - X - Y - Z_1 - Z_2 20

A - C - H - I - P - R - X - Z - Z_2 19

A - E - I - M - N - U - V - W - Y - Z - Z_2 21

A - E - I - M - N - U - V - W - X - Z_2 20

A - E - I - M - N - U - V - X - Y - Z_1 - Z_2 23

A - E - I - M - N - U - V - X - Z - Z_2 22

A - E - I - M - N - U - X - Y - Z_1 - Z_2 36

A - E - I - M - N - S - X - Z - Z_2 35

A - E - I - M - O - U - V - W - Y - Z_1 - Z_2 21

A - E - I - M - O - U - V - V - W - Z - Z_2 20

A - E - I - M - O - U - V - X - Y - Z_1 - Z2 23

A - E - I - M - O - U - V - X - Z - Z_2 22

A - E - I - M - O - S - X - U - Z_1 - Z_2 36

A - E - I - M - O - S - X - - Z - Z_2 35

A - E - I - T - U - V - W - Y - Z_1 - Z_2 14

A - E i - T - U - V - W - Z - Z_2 13

A - E - I - T - U - V - X - Y - Z_1 - Z2 16

A - E - I - T - U - V - X - Z - Z_2 15

A - E - I - T - S - X - Y - Z_1 - Z_2 29

A - E - I - T - S - X - Z - Z_2 28

A - E - I - P - D - X - Y - Z_1 - Z_2 15

A - E - I - P - R - X - Z - Z_2 14

A - E - I - P - U - V - W - Y - Z_1 - Z_2 13

A - E - I - P - U - V - V - Z - Z_2 12

A - E - I - P - U - V - X - Y - Z_1 - Z_2 15

A - E - I - P - U - V - Y - Z - Z_2 14

A - E - I - P - S - X - Z_1 - Z_2 28

A - E - I - P - S - X - Z - Z_2 27

A - B - D - K - L - O - R - X - Y - Z_1 - Z_2 24

A - B - D - K - L - O - - V - W - Z - Z_2 23

A - B - D - K - L - O - U - V - W - Y - Z_1 - Z_2	22
A - B - D - K - L - O - U - V - W - Z - Z_2	21
A - B - D - K - L - O - U - V - X - Y - Z1 - Z2	24
A - B - D - K - L - O - U - V - X - Z - Z_2	23
A - B - D - K - L - O - S - X - Y - Z_1 - Z_2	37
A - B - D - K - L - O - S - Y - Z - Z_2	36

Determination of the Earliest Start and Finish Times

The Network, fig 1. is used to determine time required for each activity. Below are the symbols used.

S = Earliest possible finish time for the project

Es = Earliest possible starting time for a given activity.

T = Time required to complete a given activity.

Ef = Es + T = Earliest possible finish time for an activity.

F = Earliest possible finish time for the project.

If the first activity A began on June 1st 1981, the installation project starting time S = 0

T = 0, Es = 0

It is to be noted here that T = 0 because this work is concerned only with the period from when all items have been uncrated.

Therefore

Ef = Es + T = 0 + 0 = 0

considering the first path:-

A - F - N - U - V - W - Z - Z_2, the next activity is F which can be started at the same time, since Ef (A) = 0. Activity F is followed by activity N. Now consider

Es (F) = 0, T = 2

Ef (F) = Es + T = 0 + 2 = 2 i.e. June 3rd.

For Activity N to start, all of its predecessors must have been completed. The predecessor activities of N are F, J and M. Thus, the Es of N is determined by the Ef of F, J and M.

Clearly the deviation of the project execution could be no shorter than the most time consuming route or path. From the above two routes have the same longest time of 42 days. These are $A - C - G - J - O - S - X - Y - Z_1 - Z_2$ and $A - C - G - J - N - S - X - Y - Z_1 - Z_2$. These two longest routes are referred to as the "critical" paths, since any further delay in any of these paths would only further delay the whole project. Other routes contain "slacks" which represent the amounts of time by which delay can be caused in such routes without causing any delay on the whole project.

Latest Start and Finish Times.

In order to determine the earliest start and earliest finish of any activity, the starting time of the project had to be specified; thence activity time T was added to obtain the earliest finish of the next activity. The subsequent activity's earliest start was derived from the preceeding activity's earliest finish. Then, progress was made from project start to finish. To obtain the latest possible start and finish time for each activity, given that the target date is to be met (critical time), we then begin with the target date and work backwards.

The target time for this project is 42 days after its early start time. Therefore, the target date cannot be earlier than the finish time. The computation for the various times are derived viz:-

If Tc = Target completion time for the project or the latest possible finish time for the project.

Lf = Latest possible finish time for a given activity if the target completion time Tc is to be met

t = Time required to complete a given activity

Ls = Lf - t = Latest possible starting time

for a given activity if the target completion time

Tc is to be met

From the network, for activity Z_2

Lf = T = 42 days

t = 0

Ls = Lf - t = 42 - 0 = 42 days

For activity Z

Ls of Z_2 = Lf of Z = 42 days.

t of Z = 2 days

Ls of X = 42 - 2 = 40 days

Slack is computed from Ls - Es or Lf - Ef

e.g. for activity D,

Ls = 33, Es = 20, Lf = 35 Ef = 22

Thus, Ls - Es = 33 - 20 = 13 days

Lf - Ef = 35 - 35 = 13 days

The various times computed are contained in Table 4.

TABLE 4

Summary of Expected times

Earliest start = (Es); Latest start = (ls); Early Finish = (Ef);

Latest Finish = (Lf); Slack = (Lf-Ef).

ACTIVITY	PREDECESSOR ACTIVITY	EARLIEST START(Es)	LATEST START(Ls)	EARLIEST FINISH(Ef)	LATEST FINISH(Lf)	SLACK (Lf-Ef)
A		0	0	0	0	0
B		0	18	1	19	18
C		0	0	3	3	0
D	B	1	19	7	25	18

ACTIVITY	PREDECESSOR ACTIVITY	EARLIEST START(Es)	LATEST START(Ls)	EARLIEST FINISH(Ef)	LATEST FINISH(Lf)	SLACK (Lf-Ef)
E		0	6	1	7	6
F		0	10	2	12	10
G	C	3	3	7	7	0
H	C	3	4	6	7	1
I	E,H	6	7	8	9	1
J	G	7	7	12	12	0
K	D	7	25	11	29	18
L	K	11	29	12	30	18
M	I,J	8	9	11	12	1
N	F,J,M	12	12	19	19	0
O	F,J,M	12	12	19	19	0
P	I	8	30	10	32	22
Q	L	12	30	14	32	18
R	P,Q	14	32	17	35	18
S	P,Q,N,O,T	19	19	35	35	0
T	I	8	16	11	19	8
U	P,Q,N,O,T	19	32	20	33	1
V	U	20	33	22	35	3
W	V	22	37	24	39	15
X	R,S,T	35	35	39	39	0
Y	W,X	39	39	40	40	0
Z	Y	40	40	42	42	0
Z1	Z	40	40	42	42	0
Z2	Z1 Z1	42	42	42	42	0

Reduction of Time and Cost.

The longest paths of the network are:-

A - C - G - J - O - S - X - Z - Z_1 - Z_2 = 42 days

A - C - G - J - O - S - X - Z - Z_2 = 41 days

A - C - H - I - M - N - S - X - Y - Z_1 - Z_2 = 41 days

A - C - H - I - M - N - S - X - Z - Z2 = 40 days

A - C - G - J - N - S - X - Y - Z_1 - Z_2 = 42 days

A - C - G - J - N - S - X - Z - Z_2 = 41 days

Activity C is common to all of these paths and represents a 3 day job. It had been shown earlier that a complete substitution of Nigerian engineers was possible in this job. Although activity C is on the critical path, the other initial activities B, E and F have also been shown to require only the input of the Nigerian engineers. Hence, a total of 3 days can be reduced from the project time of 42 days to 39 days. Activities Y and Z_1 are also a source of reduction of another 1 day if the strength is increased.

Critical Path Elements

From Table 5 below, it will be seen that the elements that constitute the critical path are essentially those requiring high technology.

TABLE 5

From Table 2 and 3

ACTIVITY	DESCRIPTION OF WORK	REDIFFUSION ENGRS.	REDIFFUSION TECHNICIANS	NIGERIAN ENGRS.	LABOURERS	TOTAL DAYS
C	Set up Bays 07, 08 etc.			2	8	3
G	Cabling of Inter-connections	1		2	2	4
J	Powering up of devices	2	2	2		5

ACTIVITY	DESCRIPTION OF WORK	REDIFFUSION ENGRS.	REDIFFUSION TECHNICIANS	NIGERIAN ENGRS.	LABOURERS	TOTAL DAYS
O	Novoview system set up	2		2		7
N	Powering up flight deck	2		2		7
S	Test flight	2		2		16
X	Motion Test	1		1		4
Y	Clear surrounding				6	1
Z_1	Seal entrance					

Recommendations for Cost Reduction.

From the PERT Network analysis, it is obvious that the installation work could be reduced to 42 days, as shown by the critical path. Crash considerations of activities C, Y and Z_1 will further reduce the project time to 38 days. This represents a time saving of 11 days over the 49 days produced by the Gantt Chart as decided by Messrs. Rediffusion Simulation Ltd. The cost implication are now calculated as below:

Personal emoluments.

	REDIFFUSION ENGINEERS	REDIFFUSION TECHNICIANS	NIGERIAN ENGINEERS	LABOURERS	TOTAL
NUMBER	8	6	4	20	38
Remuneration perday per person	₦100.00	₦ 70.00	₦ 15.78	₦ 4.17	₦189.95
Using Gantt 49 days total	₦39,200	₦20,580.00	₦3,092.88	4,086.60	₦66,959.48
Using PERT 38 days total	₦30,400	₦15,960.00	₦2,398.56	3,169.20	₦51,927.76

Hotel accomodation and feeding for 49 days at ₦70.00 per person per day for 14 persons = ₦48,020.00

Hotel accommodation and feeding for 38 days at ₦70.00 per day per person for 14 persons = ₦37,240.00

Using Gantt Chart, total personal emoluments (Allowances and accommodation) = ₦66,959.48 + ₦48,020 = ₦114,979.48

Using PERT method, total personal emoluments (Allowances and accommodation) = ₦51,929.76 + ₦37,240.00 = ₦89,167.76

The difference represents the savings on the personal emoluments = ₦25,811.72.

This represents 22% savings in cash and a reduction of 11 days in project execution time. The time savings is another 22% savings as well.

If the Simulator was immediately put into use, the daily turnover (16 hours flying per day at ₦200/hr) ₦3200.00. During the 11 days (2 days rest), the turnover would be ₦28,800.00.

Running Costs.

Total personal emoluments per annum	= ₦56,000.00
Fuel and lubrication for Generating set annually	= 25,000.00
Depreciation on all machinery/ annum + incidentals etc.	= 400,000.00
	₦481,000.00

Daily running cost = ₦1,317.81

For 11 days, running cost = ₦14,495.89.

Income.

The income therefore in the 11 day period would be ₦28,800 - ₦14,495.89 = ₦14,304.11.

From the foregoing, the cash benefit of the installation using the technique of network would have been ₦25,811.72 + ₦14,304.11 = ₦40,115.83

The elements of the critical path point out the great dependence of the installation exercise on high degree of technical know-how; such as the ability to understand the use of diagnostics, test routines, and a good working knowledge of electrical and electronic cabling. It will therefore be highly advantageous if part of the training programme for the engineers lays some emphasis on the practical knowledge which could enhance installation.

CHAPTER FOUR

SUMMARY AND CONCLUSIONS

For enhanced safe air navigation, aircraft operators around the world have come to recognise the use of the flight simulator as an indispensable tool of training. Likewise, simulator manufacturers have over the years been very responsive to the growing need of the airlines. Having started from the simplest and most crude form called the "Blue Box" (after Edward Link), especially with the military backing in the USA during the World War II, the flight simulator has undergone series of 'methamorphosis' into its present day shape; complex instrumentation, new facilities including visual and motion simulation and high degree of simulation fidelity. To achieve this tremendous feat, a lot of investment has been made in research and development. Today, simulators have been produced with such degree of reliability that total transition training can be effected without actual time or the live aircraft (Zero-flight time).

In 1981, the Nigerian Civil Aviation Training Centre, Zaria, installed an F28 Simulator which was purchased from Messrs Rediffusion Simulation Ltd of England at the cost of US $4m. The installation was carried out by a combined team of Rediffusion and Nigerian engineers. The programme of installation was prepared by Rediffusion in their manual titled Breakdown and Installation Plan. This plan was purely a Gantt Chart which proposed a 49 day project time. The actual time recorded was fifty-five days due to late arrival of some of the machineries needed to effect the installation.

A retrospective study of the installation project was made at the request of the researcher. Personal interviews were made with the Nigerian Participants in the installation. Records of the activities were examined together with the Gantt Chart. It was decided to apply PERT Network analysis in order to determine its suitability as a better method of managing the installation in order to save time.

In order to apply PERT method, a breakdown of all of the activities was made. Data collected from the installation included all of the sequences of the identified activities (in some cases many activities comprised a Gantt task). The times taken to execute such activities were also obtained. Information on material requirements, use of cranes, fork lift and aircraft facks were also obtained. Data on personnel (foreign and local counterpart) and skills and manual labour imput were also gathered. Problems encountered during the installation were also studied. After a thorough understanding of how the installation was carried out in 1981, the researcher then proceeded to apply the technique of Network analysis to the installation data.

Thirteen Gantt tasks were proposed in the installation plan. In the PERT method, twenty-five activities were identified. A comparison of the Gantt tasks was made with the PERT activities derived in order to show the relationships. From the PERT table produced, a PERT Network was prepared and the critical Paths were identified. The elements of the critical paths were also examined in order to make recommendations that could be found useful to such installations in the future.

The study and analysis of the installation through the technique of Network Analysis have shown the following:-

1. The proposed 49 day installation time could have been reduced to 38 days with a time saving of 11 days.

2. Personal emoluments that could have been saved by use of the PERT Network Analysis amounted to ₦25,811.72 (Twenty-five thousand, eight hundred and eleven Naira, Seventy-two kobo only).

3. Time saved could have been put to use by selling simulator training time.

4. Income that could have been further derived from the saving produced by the application of PERT amounted to ₦14,304.11 (Fourteen thousand, three hundred and four Naira, eleven kobo only) by putting the simulator to use at the saved time.

Recommendations

1. The technique of Network Analysis when applied to the installation of the F28 Simulator can save time and money. Future installations should follow the network produced.

2. Elements of the Network have shown gross underutilisation of the Nigerian engineers. Therefore, future plans should be negotiated on the basis of a Network Analysis as the one produced in this work in order to identify the extent of local input so as to save costs.

3. If access to the computer room were possible from outside the building, more time could have been saved in the whole installation.

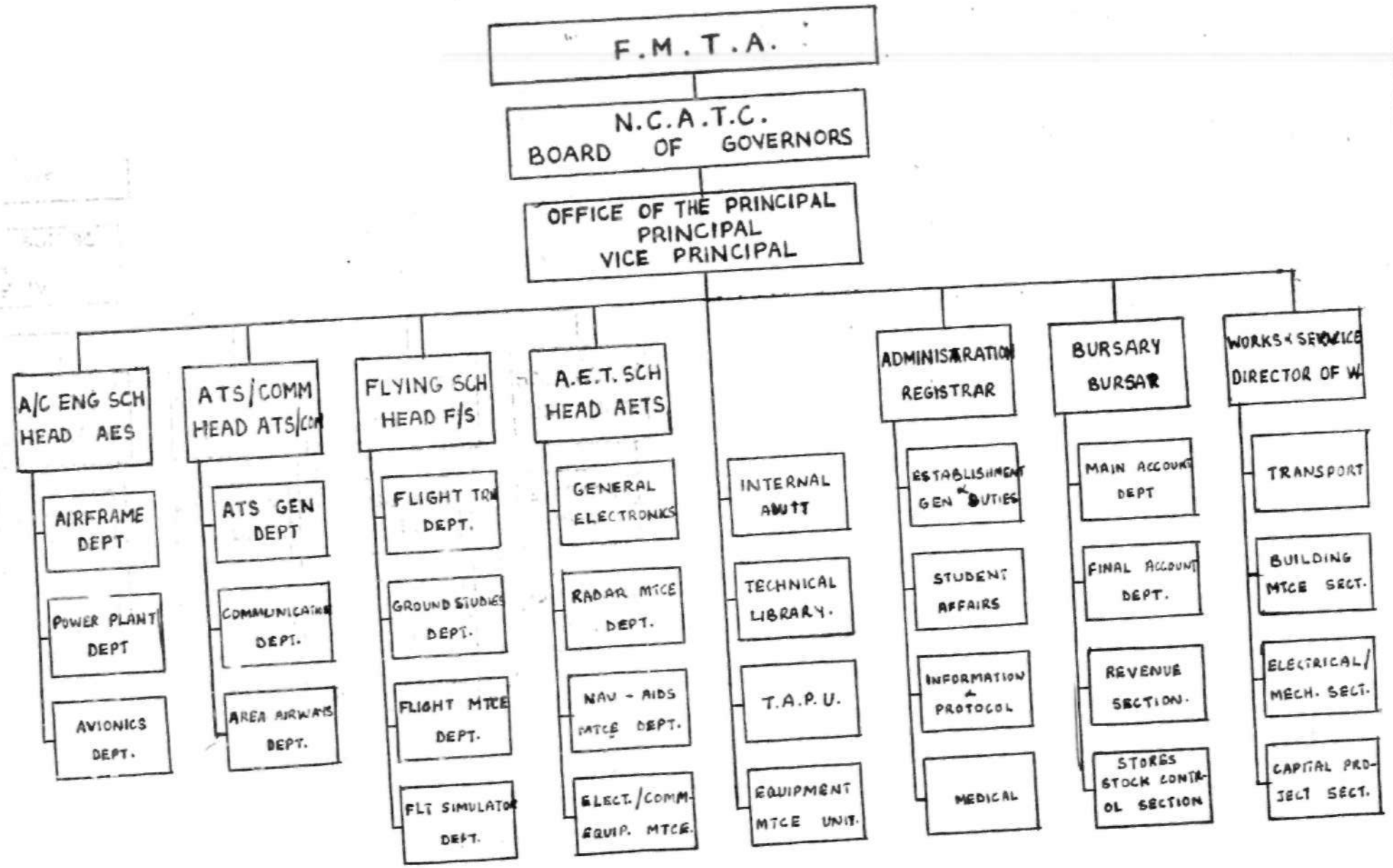
4. Elements of the critical paths have shown the large dependence of the installation fime on knowledge of high technology. It is, therefore, strongly recommended that future Nigerian Simulator Engineers should be further trained in order to be able to participate more in the more complex activities of installation.

5. It is hoped that if the next installation of a simulator at the same facility is to be carried using the network produced from the previous installation, the technique applied will be fully justified.

Unit or Assembly	Width m.	Length m.	Height m.	Estimated Weight Kg.
Bay 07	1.867	0.711	2.007	680
Bay 08	1.867	0.711	2.007	680
R2000A Computer	0.787	0.762	1.067	272
Static Inverter	0.584	0.763	1.905	272
Desk	1.828	0.762	0.762	26
Novoview I.G.	0.597	0.787	1.574	136
Electric Typewriter	0.546	0.393	0.241	20
Reader-Punch	0.486	0.508	0.254	22
Line Printer	0.76	0.508	0.228	38.5
Typewriter Stand	0.508	0.457	0.609	12
Fuselage A/C	3.66	2.44	0.91	4536
M.C.C. Unit	0.583	0.533	1.524	181
H.P.U. Complete	3.53	2.438	1.80	6,350.4
Motion Actuator (6 Off)	0.100 dia	1.852	? -	125
Hydraulic Accumulator	0.350 dia	0.53	-	200
Fuselage plus Platform	4.5	6	3.9	8,576

APPENDIX A

Dimensions of some of the Major Assemlies.


F.M.T.A.
N.C.A.T.C.
BOARD OF GOVERNORS
OFFICE OF THE PRINCIPAL
PRINCIPAL
VICE PRINCIPAL
A/C ENG SCH
HEAD AES
AIRFRAME DEPT
POWER PLANT DEPT
AVIONICS DEPT.
ATS/COMM
HEAD ATS/COM
ATS GEN DEPT
COMMUNICATIONS DEPT.
AREA AIRWAYS DEPT.
FLYING SCH
HEAD F/S
FLIGHT TRG DEPT.
GROUND STUDIES DEPT.
FLIGHT MTCE DEPT.
FLT SIMULATOR DEPT.
A.E.T. SCH
HEAD AETS
GENERAL ELECTRONICS
RADAR MTCE DEPT.
NAV - AIDS MTCE DEPT.
ELECT./COMM-EQUIP. MTCE.
INTERNAL AUDIT
TECHNICAL LIBRARY.
T.A.P.U.
EQUIPMENT MTCE UNIT.
ADMINISTRATION
REGISTRAR
ESTABLISHMENT & GEN DUTIES
STUDENT AFFAIRS
INFORMATION & PROTOCOL
MEDICAL
BURSARY
BURSAR
MAIN ACCOUNT DEPT
FINAL ACCOUNT DEPT.
REVENUE SECTION.
STORES STOCK CONTROL SECTION
WORKS & SERVICE
DIRECTOR OF W
TRANSPORT
BUILDING MTCE SECT.
ELECTRICAL/MECH. SECT.
CAPITAL PROJECT SECT.