THE NATIONAL SPACE CENTRE, ABUJA.

A CELEBRATION OF TECHNOLOGY.

BY

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CERTIFICATION

This thesis entitled, "**THE NATIONAL SPACE CENTRE, ABUJA; A celebration of technology.**" By Ajijola, Abdulkarim, meets the regulations covering the award of the degree of Master of Science in Architecture of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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DECLARATION

I hereby declare that this thesis has been composed by myself, and it is a record of my original research work. It has not been presented in any previous examination for the award of a degree. All quotations and sources of information are distinguished and acknowledged by means of reference and bibliography.

_____

Abdulkarim Ajijola

March, 2004

DEDICATION

To my parents for supporting me in all my pursuits and to Almighty Allah.

ACKNOWLEDGEMENTS

In carrying out this project, I am sincerely grateful to the following people without whose support and contributions, this work would not have been possible.

My parents, Alhaji and Mrs. A.D.Ajijola, for their unflinching support throughout the duration of my course, Arc. Dr. W.B.Qurix, my supervisor, for his valuable and advice and suggestions all through the project. Arc. A.S.Salisu, my deputy supervisor, for his numerous contributions and unwavering support during the project, Arc. S.S.Tulpule for encouraging me and his interest in my work, and also, Arc. M.L.Sagada for all his help without which things would have been much more difficult. All my friends in the class especially Kabir Yabo, Tony Afama and Muktar Garba, who were always there for me. Special thanks to Jamila and Saa'da for their support.

All staff, students and friends who gave me physical, mental and moral support throughout the duration of this thesis.

And to Almighty Allah for giving me the strength to see it through.

QUOTATIONS

"I once asked Mies van der Rohe, then my faculty colleague at Illonois Institute of Technology, how he got the opportunity to build the Tugenhadt house – a startingly modern design at the time of its construction. The prospective owner had come to Mies after seeing some of the quite conventional houses he had designed earlier in the Netherlands when he was still an apprentice.
"Wasn't the client shocked," I asked "when you put him before your glass and metal design?" "Yes," said Mies, viewing the tip of his cigar reflectively," he wasn't very happy at first. But then we smoked some good cigars,… and we drank some glasses of a good Rhein wine,… and then he began to like it very much."

Herbert Simon, The Sciences of the Artificial, 3rd Edition., p. 151

ABSTRACT

The Space Centre is a building entirely driven by Science. There is a powerful symbiosis between Architecture and Science including the application of Science which is known as Technology. For most Architects however, their dream project is an art museum in the realm of the Guggenheim in New York and Balboa as well as the Tate in London. The Space Centre is poised to replace the art museum as the architectural icon of the 21st century. The Space Centre is one of a new worldwide generation of interactive buildings concerned with not only, rockets, satellites and space travel, but more widely with our place in the cosmos. It is a scientific building, constructed as a kind of scientific experiment itself!

A Space Centre is regarded as a resource centre for information and research on Space Science and Technology (SST). Facilities are thus provided for the enhancement of knowledge and understanding of Space and related fields, not only for the professionals and experts in these disciplines but more importantly for the average people who constitute the bulk of our population. It should serve to stimulate interest in Space Science and Technology and eventually lead to an upliftment of the quality of life of humanity in general.

One of the greatest problems impeding our aspirations as a nation is a general lack of competence in science and technology. Part of the problem responsible for this situation is the perception that science and technology has no direct relevance to our day to day lives and that modern science and its applications or technologies is out of our grasp. Also, formal and monotonous methods of learning in our society serve to deter many who would otherwise be interested in the areas of study.

An attempt has therefore been made to create an environment that is conducive for learning in an informal manner that is both stimulating yet un-intimidating to the general public. The Space Centre will also serve to inform the general public about solar and lunar eclipses, meteor showers and other events as well as arrange courses and seminars on astronomical topics and give talks on a variety of related issues. The general public will also benefit through publications, press releases and other forms of media presentations.

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1.0 CHAPTER ONE

INTRODUCTION

1.1 THE HISTORICAL BACKGROUND

Our interest in space is nothing new. Since the dawn of civilization, space has played a big part in our mythology, religions and folklore. The ancient Greeks and Romans named the planets after their gods.

Other civilizations also linked the planets with gods and mythical tales. The word 'planet' comes from the Greek term for **wanderer** and the motion of planets across the sky was among the first observations documented by early astronomers.



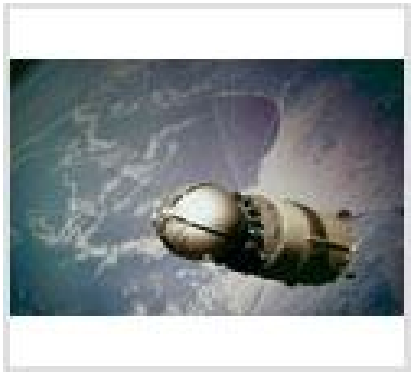
PLATE 1.11 The planets.



PLATE 1.12 Galileo.

It was the invention and refinement of telescopes that first expanded our knowledge of universe. One hundred years ago, the frontier of human exploration was at the poles of our earth.

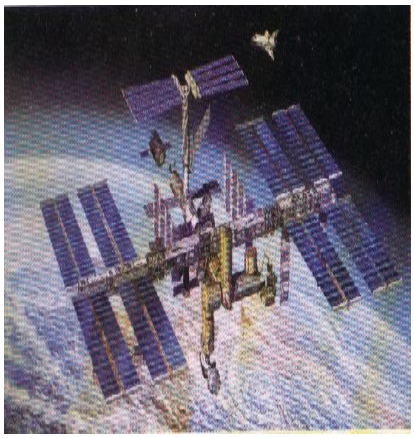
Then came the age of space exploration and new opportunities to explore our neighbouring worlds in space.



This age began on the 4th of October 1957 with the launch of Sputnik 1 by the Soviet Union. Sputnik 1 was the first artificial satellite to orbit the earth.

PLATE 1.13 Vostok 1 in orbit.

The first manned space flight was made on April 12, 1961, when Yuri Gagarin, a soviet cosmonaut, orbited the earth in the spaceship, Vostok 1.



Today, the new frontiers of human exploration lie far beyond the earth, extend through our solar system, across interstellar space, and reach out to galaxies billions of light years away.

PLATE 1.14 Artists impression of the International Space Station.

Over the years, mankind has benefited from advances in space science and technology in many areas including satellite communications, remote sensing and meteorology among others.

In Nigeria, these benefits have however have usually been accrued to us indirectly as consumers of products and services provided by multinational companies or intergovernmental agencies such as INTELSAT, INMARSAT, RASCOM, COPUOS, etc.

1.2 THE NATIONAL SPACE POLICY

The **Vision Statement** of the National Space Policy is "To make Nigeria build indigenous competence in developing, designing and building appropriate hardware and software in space technology as an essential tool for its socio-economic development and enhancement of the quality of life of its people."

Nigeria cannot presently claim to possess the technical ability to participate actively and independently in space related activities as a service provider. It has therefore remained a nation of consumers of space-derived products.

There is no nation that can call itself developed in the 21st century that does not have an indigenous critical mass of trained space scientists and engineers who contribute actively to the solutions of the nation's problems. Such critical mass can only be actively acquired through a well defined and developed country space program.

It is therefore, self-evident that scientific and technological development of Nigeria as a people and a nation will be partly anchored on its commitment to continuously master, develop and utilize the by-products of space technology to address her diverse socio-economic problems.

The Government shall also put in place an institutional framework that will oversee all the Space Science and Technology activities in the country under an apex organ to be called the **National Space Council**.

The membership of the **National Space Council** shall include:

i. His Excellency, Mr. President
ii. His Excellency, Mr. Vice President
iii. National Security Adviser
iv. Minister of Defence
v. Minister of Internal Affairs

vi. Minister of National Planning

vii. Minister of Communications

viii. Minister of Science and Technology

ix. A private sector representative

x. Two distinguished scientists



PLATE 1.15 NigerSat-1 before launch.

The Ministry of Science and Technology, which co-ordinates and supervises the activities of the National Space Research and Development Agency, will provide the secretariat.

There shall also be two advisory committees; **Technical Advisory Committee** and a **Committee on International Cooperation**.

Space Science and Technology is multi-disciplinary, therefore it is necessary to establish centres of excellence and an institutional framework to develop the relevant fields and coordinate various programs for the attainment of the national space capability. In order to achieve the objectives of these policies, therefore the following activity centres shall be established by the government.

a. Centre for Basic Space Science.

b. Centre for Remote Sensing.

c. Centre for Satellite Technology Development.

d. Centre for Geodesy and Geodynamics.

e. Centre for Space Transport and Propulsion.

f. Centre for Space Science and Technology Education.

And any others it may deem necessary in the future.

The priority project in the field of Basic Space Science will be to build a National Space Centre / Planetarium in Abuja.

1.3 AIMS AND OBJECTIVES

AIMS:

The principle aim of this project is to popularize space science and other sciences. Such a facility will also enhance the understanding of Nigerians of their place and role in the universe as well as serving to showpiece Nigeria's contributions to space science and technology.

The **National Space Centre** shall enhance the development of the following areas of space science and technology:

I. **Basic Space Science and Technology** which is the understanding of how the universe works and its impact on our world.

II. **Remote Sensing** which involves the understanding and management of our environment and natural resources using space-acquired information.

III. **Satellite Meteorology** which is the study of atmospheric and weather sciences using satellite data to facilitate the effective management of our environment.

IV. **Communication and Information Technology** in order to provide efficient and reliable communications in order to enhance the growth of the industrial, commercial and administrative sectors of the economy.

V. **Defence and Security** in order to develop space science and technology programmes that will address the national defence requirements of the nation.

OBJECTIVES:

The principle objective of this project is to provide a stimulating environment for the understanding space science and other applied sciences. The building itself should reflect mankind's technological development in space science and technology as well as being responsive to our ever increasingly sophisticated requirements from a building.

SCOPE AND LIMITATIONS

SCOPE:

The scope of this thesis research is primarily to design a Centre for Space Science and Technology for Nigeria. The design emphasis will be on Architecture and Technology and how they can be used to improve our lives. The building itself should impart this message to the onlooker/user.

Finally, the thesis write up which will also highlight other factors such as an introduction, background data, design report, design concept, etc.

.CONSTRAINTS / LIMITATIONS

Despite of the lack of relevant case studies in our immediate environment, efforts will be made to carry out a thorough study of the topic in order to justify the thesis proposal.

Difficulty in acquiring design data on foreign Space Centres may hamper the study.

Also the climatic and environmental difference between Nigeria and most of the countries where existing structures are built may limit the relevance of these case studies.

The time limit for the thesis work is also a disadvantage.

1.4 JUSTIFICATION

Many Nigerians ask “why do we need to be interested in Space Science and Technology in the first place?” It often appears to be an abstract concept.

This itself is the primary justification for the establishment of the National Space Centre.

The need for Space centres as the prime weapon in the battle for science literacy has never been greater. Never before has science known so much about the universe as we do today, never before have we acquired new information about the cosmos as quickly as we do now. Yet, never before has the general public been so ignorant about the basic facts of Space Science.

Space is the greatest unknown, and perhaps the greatest adventure. It encapsulates the entire universe, including all that has been explored on Earth, and therefore everything humanity stands for. The belief that man can explore space transcends the problems of everyday life.

It is not an impossible feat, and the exploration has already begun. Those who refuse to pay attention will simply be left behind.

The goals of space exploration will change with time, experience and technology. When we think about our reasons for going into the unknown and taking risks, we should consider the generations that will follow us. Perhaps the question of **why we should go into space** is no longer relevant: we should simply be acknowledging that we will.

Mankind's conquest of space is the ultimate quest for survival of our species.

1.5 METHODOLOGY

In the course of this research, information and data shall be collected from primary and secondary sources. Basic data from the Federal Ministry of Science and Technology will be significant as well as data from various case studies.

A comprehensive literature review including the study of books, journals, past thesis projects, seminars, papers and other documents will be undertaken.

Designs of similar buildings will be used as case studies with the aim of understanding the design approaches used by the architects and noting the salient points of their resulting designs.

A thorough site study will also be carried out, this will include the study of the existing site situation, study of relevant surveys, photographs, climatic data, demography, zoning, etc.

Deductions from personal observations will also be analyzed and synthesized with the aim of correcting aspects perceived from observations as not being thoroughly solved and thus enabling the implementation in the project of solutions which adequately remedy these problems with respect to our environment.

The above are the basic areas to be investigated and their results utilised in executing the proposed project. Where data was insufficient, intuitive decisions were implemented which hope to achieve the intended objective of the project.

2.0 CHAPTER TWO

LITERATURE REVIEW

As architects, and because of the fact that our work is often seen as technology based, it is often assumed that we are more concerned with science than art, but this is not the case. We see ourselves more as artists than technicians and our primary concerns are with aesthetics, not calculations. We like to use the latest technology but we also passionate about what our buildings look like and how they feel like inside. Similarly, while we try to push the technological boundaries of buildings, we also want them to look good

2.1 THE GENERAL CONCEPTS OF ARCHITECTURE, TECHNOLOGY AND ART.

The Space Centre is a building designed for the promotion of Space Science and Technology. All that is needed to house the usual contents of such buildings is just a big windowless box. However, to the Architect, such an approach is untenable. The building envelope and form must make a definite statement about its' function. *The Sunday Times of 03.06.01, in an article titled, "Ready for Lift off",* describes

the new wave of Science Centres and wonders if they will appeal to the general public in the same way as contemporary art galleries. While acknowledging that Space and Science Centres do not yet have the same appeal of art buildings, fame-wise, it emphasises the strong relationship between Architecture and Science.

Reference is made to Professor Lisa Jardine who has established how the architecture of Sir Christopher Wren (also a mathematician, astronomer and Royal Society member) drew on the expertise of other scientists of his time. Most notably, his friend and colleague, Sir Robert Hooke. Wren's buildings, she convincingly suggests are conceived as vessels for experimentation and observation.

Crosby Michael J.(2000) describes Space Centers as products of Science and wonder while *Eyre Jim (2001)* tells us that the most powerful sensation a structure can provoke is a sense of **wonder.** This combines admiration with a 'wow factor' – usually something outside the normal range of experience. Although, in the art world, immediacy is not always considered an attribute, in the world of engineering, structures that exhibit a clarity of thought and execution have a very direct appeal.

Ultimately, technology is only a means to an end.

We are fortunate to be living in an age of advanced technology which allows us to design and construct much

more sophisticated forms than before but
we still cannot compete with nature which still provides us with the ultimate source of inspiration.

Similarly, in an article, *Bricks and Mortar, by Stephen Moss in The Guardian of 29.09.2001*, Jeremy Till, Professor of architecture at the University of Sheffield and a judge at the 2001 Royal Institute of British Architects (RIBA) awards **describes a building as being as much a concept as a structure**. Professor Till goes on to reject a lot of discussion about the iconic status of buildings.

Says Till "Looking at this years Stirling Prize shortlist, I was very happy that a doctors surgery in Hammersmith got on, because it is one of the few examples on the list that isn't extraordinary, in the sense of being removed from everyday life. Instead, it takes a very ordinary set of conditions and makes them special." The Stirling prize is awarded by RIBA for best building of the year. Professor Till believes that the way a building looks is irrelevant and offers the idea of "space"; how architects and designers allow us to use their structures.

These arguments are anathema to many architects. Ian Davidson, chairman of the RIBA awards panel, names beauty, usefulness and innovation as the criteria by which he judges good architecture, a modern reading of the Roman architect, Vitruvius, who specified "commodity, firmness

and delight". The appeal of Professor Tills' thinking is that he starts with people rather than structures, and asks us not to venerate buildings but to occupy them. He postulates that architecture is the here and now, not that monument shrouded in the mist in the distance.

Perhaps also, Architecture can be a natural bridge between art and science.

2.2 PAST EXAMPLES

Although beautiful and significant buildings have been produced in every society since ancient times, architects first laid a lasting claim to the responsibility for designing them during the Italian Renaissance.

In the past, the differences between art and science were less pronounced and the quintessential Renaissance man, **Leonardo da Vinci**, succeeded in being a Master Artist, Scientist and Architect.



PLATE 2.11 Leonardo Da Vinci.

The patronage of the new city-states and a wealthy merchant class encouraged the expression of a new sense of monumentality and a new style. Beginning in the late 14th century, patrons who wanted to sponsor special buildings looked for talent among craftsmen who were trained in design and experienced in managing large workshops. Most architects of the early Renaissance, therefore, came from the ranks of stonecutters (on their way to becoming sculptors), goldsmiths, cabinetmakers and painters. *Magali Sarfati Larson, Behind the Postmodern Façade, Architectural Change in Twentieth Century America, 1996*.The fifteenth century brought new requirements: State architects were frequently involved in civil engineering projects, notably hydraulic works; more important, improvements in artillery compelled cities to build new and more complex fortifications. Neither civic nor military buildings required new construction methods, but they did require design skills only rarely found among master masons.

Because they could rely on the established competence of workers in the building crafts, the designers of buildings were able to appropriate for themselves the intellectual task of conceiving the entire project. The first architects were not only freed from the stigma of manual work, they gained prestige from the complexity, the civic importance and the

ancient aesthetic lineage claimed for the new style of building.

Chris Wilkinson, Bridging Art and Science, 2001 explains that the distinction between architecture and engineering is relatively new.



PLATE 2.12 Florence Cathederal



When Brunelleschi, the architect and goldsmith, designed the great dome of Florence Cathederal in 1463, he also worked out the engineering and had to invent ways of constructing it as well.

PLATE 2.13 Brunelleschi.

In Victorian times, I.K.Brunel was able to engineer the Great Western Railway and design the station buildings as well. Furthermore, *Erich Mendelsohn, The Einstein Tower, Potsdam Press, 2001*, tells us that in the modern period, perhaps more than in any other, progressive ideas have cross-fertilized between the fine and applied arts.



PLATE 2.14 Paddington Station

The roots of this tendency can be seen in Art Nouveau and in the Arts and Crafts tradition of 19th century England, and it came to fruition in De Stijl, the Bauhaus and their influence.

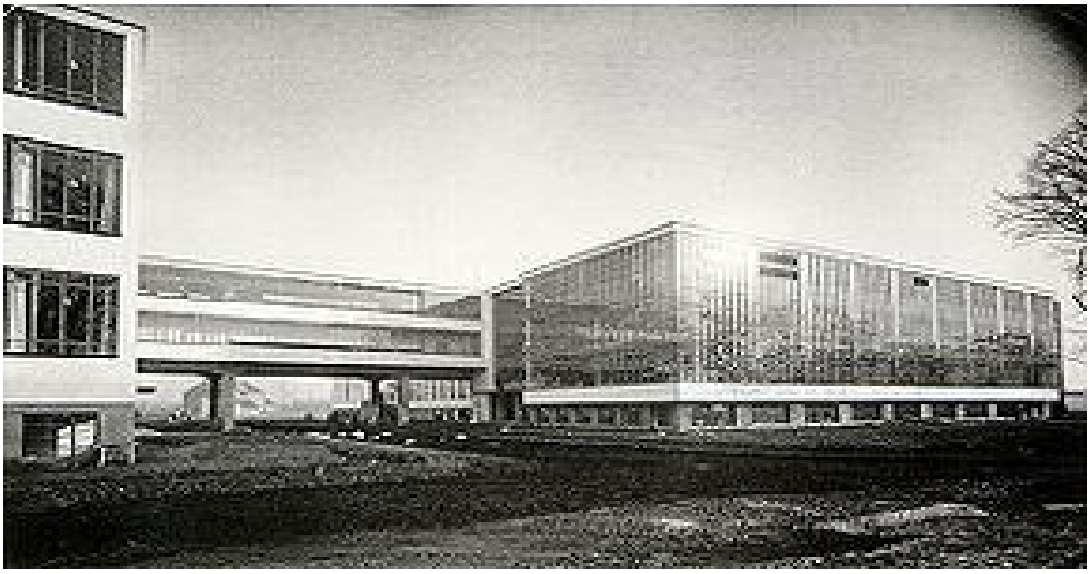


PLATE 2.15 Bauhaus Dessau

In Japan, modern architectural techniques were introduced with the Meiji Restoration of 1868. The first buildings to result from this effort combined traditional Japanese methods of timber construction with Western methods and designs.



PLATE 2.16 Kaichi Elementary School.

Information from *the Japan Ministry of Foreign Affairs website, 1999*, identifies the Kaichi Elementary School (1876) in the city of Matsumoto, Nagano Prefecture as being typical of the hybrid approach adopted for schools across the country. In the 1880s, reactionary opinion turned against the rush towards Westernization, even in Architecture and Asian models were advocated. After World War 1, traditional Japanese Architecture underwent a reassessment when architects like Frank Lloyd Wright of the United States and Bruno Taut of Germany came to work in Japan.

Later, at the start of the Modern Movement, there was more of a bias towards the arts but the importance of innovation and technology was recognized. Le Corbusier, who painted in the mornings and designed buildings in the afternoon, succeeded in combining some of the fluidity and colour of his paintings with the latest technology in his buildings. In the twentieth century, more than ever before, architects and designers sought to make creations that stand as artistic statements, while equally, fine artists have aspired to extend their practice to influence the whole environment, physical and conceptual in which we live. After the First World War, in the 1920s especially, the Modern Movement acquired new drive, as the previous stylistic approach was abandoned. The main features of the Modern Movement in architecture are well known. Due to improved communications, many innovations were soon known and adopted in different regions such as Latin America and Asia. Le Corbusiers' collaboration with architects in various countries, and his large scale urban plans in North Africa and Latin America contributed to bringing such ideas to the attention of professionals and authorities.

2.3 CURRENT TRENDS

The expansion of the market for architectural services only really happened on a substantial scale over the past century. In modern times, the vast majority of clients need a relatively standardized competence from their architects. It is true that the site, if nothing else, makes each architectural commission to some extent unique; but other requirements (including the budget) are relatively standardized for most types of buildings. Besides respecting the budget, the primary demand of the brief is that the building be adequate for the social functions it must serve

Adequacy implies a notion of at least minimal comfort and efficiency. Distinctiveness and pleasantness are secondary considerations for the typical client. The resulting standardization of architectural requirements creates a distinction between ordinary and extraordinary projects. **The standard project can be ordinary, but when a building has cultural significance, the projected building must look and feel extraordinary**. *Magali Sarfati Larson, Behind the Postmodern Façade, Architectural Change in Twentieth Century America, 1996*. By the late 1970s', architects began to design in what had previously been considered an "engineering style". In the hands of **Richard Rogers, Renzo**

Piano and Norman Foster, this had become an art form in its own right. This style was nicknamed Hi-tech, although the intriguing thing about it was that the best of these buildings, far from being naked engineering structures, were highly finished artefacts that required an extraordinary amount of sophisticated craftsmanship to complete.



PLATE 2.17 The Pompidou Centre.

They were celebrations of structural engineering as seen through the eyes of architects and in a sense their highly polished and refined of polished steelwork, pipes and ducts were as much a form of decoration as the classical columns of old. “These were ostentatious buildings and were perhaps designed to prove that an architecture that owed nothing to convention could be very glorious indeed”. Richard Rogers’ Lloyds Building and the Pompidou Centre designed with Renzo Piano are excellent examples. Further examples of

this new style of architecture include buildings that were first and foremost ‘machines’, and not for normal or regular human accommodation. Examples of these include the Financial Times Printing Press in London’s Docklands by Nicholas Grimshaw and the Satellite Receiving Station at Afleur, Austria by Gustav Peichl. *20th Century Architecture, Jonathan Glancy, 1998.*

Modernism is still the dominant force guiding our architecture today and it has been given a new impetus by recent technological developments in materials and construction, while the philosophy of deconstructionism has had a profound impact on our architectural thinking, allowing architects to escape the tyranny of “four walls and a roof”.



PLATE 2.18 Lloyds Building.

Strides in glazing technology, for example, mean that glass can be used uninterrupted on wide expanses, and architects can create different effects such as etching, printing and sandwiching things between panes.

The most profound influence on today's architects however has been digital technology, this affects not only the way business is done, allowing drawings and photographs to be sent round the world in an instant, but the very nature of space itself. Computers can create whole virtual worlds and with the aid of a mouse, we can walk round buildings, long before they are built. In her book, *40 Architects under 40, Taschen, 2000, Jessica Cargill Thompson* eulogises the New York practice, **Asymptote**, who she says create as many virtual electronic structures as they build real ones, constantly challenging old concepts about the nature of space and focussing on concepts, rather than tangible details. Their building concepts bombard users with



PLATE 2.19 Guggenheim Bilbao.

electronic information and effects, building walls out of video images and controlling environments with computers.

The tremendous advances in computer technology also mean that complex three dimensional images can be modelled relatively easily. Frank O. Gehry's Guggenheim Bilbao is perhaps the most spectacular testament to the abilities of computer modelling, but its possibilities have also inspired younger architects.





PLATE 2.2 Mobius House.(above)

PLATE 2.21 Shingeru Ban.(left)

Shuhei Endo's spirals and arches of corrugated steel, MVRDV's villa VPRO that folds in the middle, Ben van Berkel's house based on the mathematics of the Mobius band, Sancho-Madridejo's folding planes and Shigeru Ban's undulating roofs of cardboard tubing are just a few outstanding examples.



PLATE 2.22 Villa VPRO.

Countries dealing with past oppression of minorities or indigenous peoples are particularly sensitive to traditional building forms, and younger architects are increasingly rejecting Euro-centric styles that had previously dominated the architecture of their countries.



PLATE 2.23 Shuehei Endo's Spirals.

Henri Comrie + Ora Joubert explore the architectural demands of post-apartheid South Africa by acknowledging the constraints of a low-tech building industry. Simple construction methods and everyday materials are enriched through light, texture and well planned spaces, for





PLATES 2.24 and 2.25

The Gordon Institute of Business Science.

example Comrie's Gordon Institute of Business Science, which responds to climatic conditions with open shady courtyards and thick ochre coloured walls.

Another example is the Baptist Complex in Accra, Ghana by Adjaye and Russell, where modern aesthetics have been combined with traditional Ghanaian building principles. The walls are made of an adobe and concrete mix, the roofs of metal sheeting and instead of glazing, the architects specified wooden lattice screens.



PLATE 2.26 Adjaye.

2.4 THE FUTURE

The impact of development in contemporary society is so overwhelming that it is difficult to imagine what the situation was like even a few decades ago. This is particularly obvious in the field of technology. We need only think of the improved systems of communication and travel,

which have revolutionized the ways in which we live and work, and which are associated with emerging value systems and new ways of thinking.

Over the past two centuries, in fact, a new culture has come into being, and it is not limited only to one region; rather, it has rapidly expanded to cover the entire world. This new culture guides the ways we design our homes and public spaces, and establish priorities regarding developments. The rapidly increasing population has accumulated in ever-larger urban and metropolitan areas, leading to massive new building work facilitated by modern industrial production.



PLATE 2.27 Artist impression of future space exploration.

The future which our children may experience one day may entail living on a space station, in orbit or on a colony on the moon - or even the planet Mars.



PLATE 2.28. Artist impression of future moon mining.

The advent of satellite communications and the internet has resulted in a situation where the vast majority of humanity receives and consumes the same images and ideas. This does not necessarily mean that one day in the future all architecture will be the same, because people in different places have different ways of interpreting it.



PLATE 2.29 NigerSat-1 in orbit.

Clearly, the impact of technology on the future of humanity will be more momentous than the fate of any particular discipline or profession.

Nevertheless, profound changes in architecture are happening right now, and how we confront change is an urgent question. As software developer and founder of Sun Microsystems Bill Joy is concerned primarily with the ethics of design: "As a tool builder I must struggle with the uses to which the tools I make are put." Architects, however, rarely consider ethics before aesthetics. In our love affair with technology, we often forget to question its use.

3.0 CHAPTER THREE

APPROPRIATE TECHNOLOGY FOR SPACE CENTRES.

Architects have designed space related buildings since the 16th and 17th centuries – these include Sir Christopher Wrens' Royal Observatory at London, England (1675).
German Architects who worked for the Luftwaffe during the second world war (the Deutsche Arbeitsfront 'German Labour Organisation', and the Baugruppe Schlemp, headed by Architect Walter Schlempp) designed and created the assembly, launch and testing facilities at Peenemuende for the V-2 rocket.

The space facilities at the Cape Canaveral Space Centre, were built in 1962 by a consortium named URSAM, led by Architect Max O. Urbahn from New York. Urbahn designed the Vertical Assembly Building (VAB) to house four of NASAs' massive Saturn launchers, each more than 30 stories high. The launch control complex designed by Urbahn featured pivoting panels that would protect its angled glass walls from vibrations during launches. When these facilities were first designed and constructed, they received extensive coverage in architectural journals such as *Architectural Forum (September, 1963 and January, February 1967) and*

Progressive Architecture (March 1965). They were even included in the New York Museum of Modern Arts 1964 exhibition. The Kennedy Space Centre facilities, altered by other architects, are still used today for the Space Shuttle launches.

NASA has a team of trained architects working on the design of the current International Space Station (ISS), scheduled for completion in 2004-2005.

Some universal values in any concept in architecture include the visual elements of **Space, Light, Form, Structure and Materials**. These basic elements are especially relevant in the design of Space Centres.

3.1 SPACE

Architects and astronauts share a preoccupation with the exploration of space, but for architects, it is limited to the design of contained space. To envisage and design space is a fundamental aspect of the architects job and convention has made this easier by limiting sizes to what people can readily understand. Most buildings are made up of essentially rectangular spaces with modest headroom related to human proportions. In Japan, this was regularised by a traditional

formula for domestic space which was derived from the size of the ‘tatami’ mat and the way it was laid on the floor in various patterns. In post-war Britain, space standards for housing were clearly defined by the Parker Morris Standards. In both instances, innovation was discouraged and difficult to achieve. Yet throughout history, there has been a recognition of the need for spaces which are more exciting and uplifting.

The ancient Egyptians, Greeks and Romans all constructed spaces of grand proportions which were designed to inspire the people who used them. These were spaces for the Gods and they had to be beyond domestic human scale. A millennium later, the great Gothic cathedrals of Europe provided the kind of awe inspiring spaces that would make us feel humble in the sight of God. Since that time, the generators of grand spaces have changed from religion to industry, transportation, leisure and even retail! The need for huge enclosed spaces has been rapidly increasing as the technology for providing them becomes more accessible.

The term ‘universal space’ was first proposed by Mies van der Rohe to describe a kind of long-span single volume flexible enclosure. It is a kind of space that can house a wide variety of functions from industrial to transport to

sports and leisure activities. Moreover, the big single-volume enclosure is the ultimate flexible space which can be modelled to suit almost any user requirement.

More recently, the millennium dome in London goes some way in exploring this kind of structure with its huge fabric roof covering an area of approximately 80,000 metres square.

Richard Buckminster Fuller was also preoccupied with this concept which fitted in well with his philosophy of 'achieving more with less'. With the development of the innovative geodesic dome structures, he succeeded in enclosing large column free spaces with minimum weight and materials.

He took this idea further in the 1950s' with his idea for a tensegrity dome, two miles in diameter over Manhattan and although nothing of this size has been constructed, it is now technically possible.

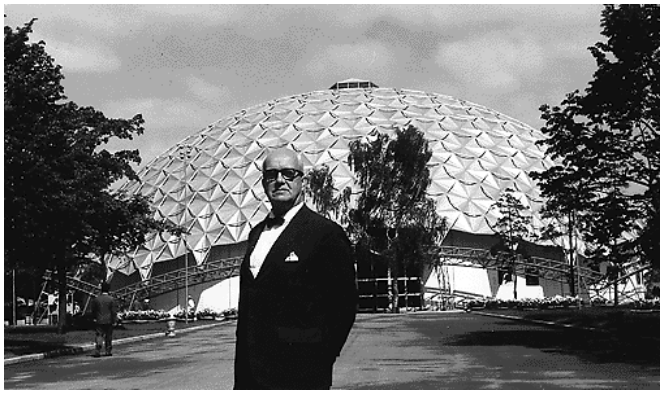


PLATE 3.11. Richard Buckminster Fuller

Supersheds (Butterworth Architecture, 1991) desribes the term ‘supersheds’ as a term which can be applied to buildings which enclose universal space and can be defined as ‘buildings enclosing a large single volume of space with relatively long spans and without major subdivisions’. The introduction starts ‘there is a kind of architecture which is not formal, decorated or mannered, but which derives its aesthetic from a clear expression of its purpose and component parts, where the demands of function and economy have led to a simplicity of form and construction, but where the basic requirements of enclosure and structure are extended by design to create buildings of quality’. This is category of buildings which has largely been excluded from the mainstream of architectural classification and left to the province of engineering. It is here however, that the skills of architecture and engineering converge. The development of these buildings has closely followed mankind’s technological progress and began in the early nineteenth century with the advent of railways and the great exhibitions in Britain, which generated the need for long-span enclosures at a time when the technology of cast iron structures was sufficiently advanced to be able to provide them.



In Britain, the 1850s' saw the construction of two buildings which exemplified the new age of architectural technology; the Crystal Palace by Joseph Paxton and Paddington Station by Isambard Kingdom Brunel.

PLATE 3.12. I.K. Brunel

Both of lightweight construction, these vast universal spaces were functional, economical and expressed simplicity of form and clarity of structure. Further technological progress has resulted in the development of vaulted structures that can span ever larger spaces and at the Paris exhibition of 1889, Cottancin and Dutert produced the first three pinned arch with a span of 114m.

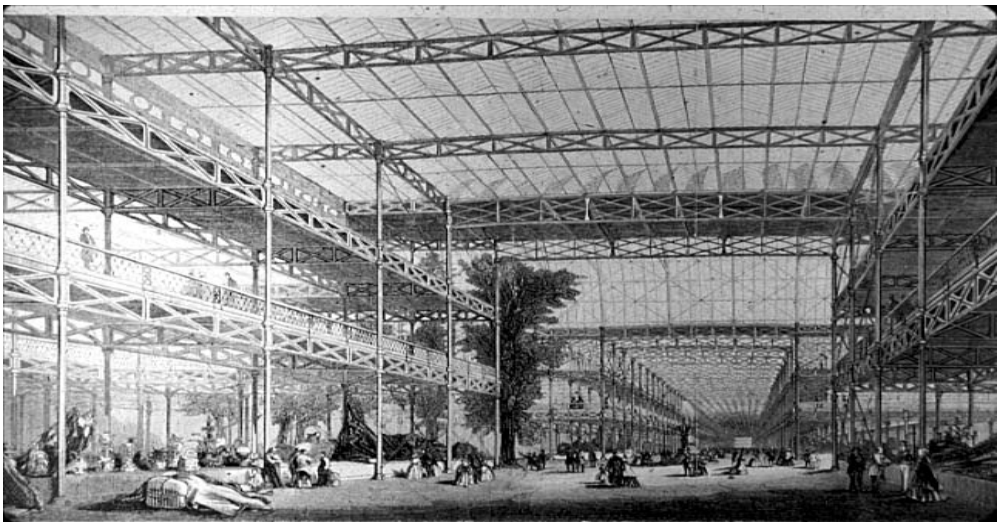


PLATE 3.13. Crystal Palace

Later developments related to airplane technology and the emergence in 1970 of the jumbo jet with its 60m wingspan, created the need for a new generation of long-span large volume buildings. The largest of these is the Boeing Assembly Plant at Everett, near Seattle, USA, which is the worlds' largest building by volumetric capacity with five bays 488 x 35m high and with clear spans of 35m.



PLATE 3.14. The Boeing Assembly Plant

In summary, there is a general requirement for large flexible spaces to house all kinds of activities, but human beings also have a fundamental need to experience space of a higher order. Perhaps we have a psychological desire to see man-made space on the same scale as nature in order to assert our place in the universe. Most of us are moved by views of a panoramic landscape and we experience a similar feeling when we enter a large public building. The inspiration and physical upliftment that can be achieved from this type of space ideally matches the requirements of space centres as places for stimulating public enthusiasm for space science and technology.

3.2 LIGHT

Light is fundamental aspect of architecture which probably reflects our innate instincts for survival, since we cannot exist without it. The concept of ‘lightness’ concerns the physical weight of property and materials, but it relates as much to the visual appearance of structures, components and even spaces. It is a quality that comes from the form, composition and economical use of materials. It also closely relates to light and the way light is utilised by the architect.

It follows therefore that buildings and structures which control light are pleasing to us.

Poets muse on the way light plays on water and there is something romantic about the reflections and the dancing movements that come from the ripples on the surface. Water can have a powerful effect on architecture by reflecting light and transmitting it onto adjacent surfaces. The magical experience of Venice with its beautiful palazzi reflected in the canals on a sunny day and the Taj Mahal in India, have inspired architects, past and present to incorporate water into their designs. Reflecting pools can add lightness and interest and this can be seen at the Hamburg Planetarium in Germany and at Explore-at-Bristol on Britain. Both succeed in enhancing the architecture with ever changing light reflections.

Similar qualities come from the play of light on the surfaces of different materials and form is enhanced by contrast of light and shade. Curved surfaces deal with light in an appealing way and a curved form will generally appear lighter than a corresponding square or rectangular form of the same volume. Projections and articulations pick up shadows and it is for this reason that traditional mouldings and decorative cornice details serve to enhance the appearance of heavy masonry buildings of the past.

Transparent and translucent materials also play with light in an interesting way. Glass is an abundant material in our lives but it still holds almost magical qualities for us. Its crystalline nature catches the light so it sparkles like jewels. Glass buildings can either appear light and transparent or solid and monumental depending upon the lighting conditions at the time. We like to be able to experience the comforts of inside while still enjoying the delights of the outside. We need light from the sun, although here in the tropics it must be controlled, it also helps us to orientate ourselves and define time.

Mies van der Rohes' Barcelona Pavilion, constructed for the world fair of 1929, was one of the early examples of the use of storey height transparent walls to allow the free flow of space and light from inside to out. This proposed a fundamentally different concept from traditional buildings, where the enclosing walls are solid with punctured openings. Here the walls and roof act as planes which define space without obstructing it, made possible by the steel-frame structure that allows the walls to be lightweight and load bearing. Another good example is the Istanbul Science Center in Turkey where the walls act as planes and define the space.

The combination of steel and glass in modern buildings has significantly lightened their apparent weight and the same effect can be achieved in multi-storey towers as in single storey examples. Even lighter weight structures can now be achieved with more recently developed technologies of composite fibres and membranes. The really high strength, lightweight materials such as carbon fibre are still expensive to use in large quantities but membrane fibres such as Teflon coated fibreglass, make economic sense for tented structures.

The control of light is also an important factor in the appreciation of space. Light from above is more powerful than from vertical planes although care must be taken when using large glazed areas to avoid excessive solar gain from sunlight. Spaces which allow penetration of natural light feel more human and friendly due to the warm colour of the light and movement of shadows which animate the space and help with orientation.

Conversely however, the core of many modern space centres are designed to appear to be artificially lit in order to give the illusion of the artificial environment which mankind needs to survive the harsh environment of outer space. A

good example is the Wellcome Wing of the Science Museum in London. In order to make the computer displays and digital displays legible, the Wellcome Wing has been designed to be dark. A blue glass wall on the west elevation combines with side walls lit by blue lighting to create an intensely blue space.

Colour is another factor which contributes to the experience of lightness. Of course, light colours help by simply reflecting the most light but the reflection of bright colours can also have more exciting effects.

Membrane structures offer perhaps the ultimate lightweight enclosure, the translucency of the fabric, the economy of materials and double curvature forms all adding to a sense of lightness. Recent developments with computer software has made form finding much easier and exciting shapes are now possible.

Adriaan Beukers and Ed van Hinte, professors from the from the Faculty of Aerospace Engineering at the University of Technology in Delft, Holland, in their recently published book, *Lightness*, refer to the inevitable renaissance of ‘minimum energy structures’. For them, lightness is not just concerned with airplanes or buildings, ‘but with the

structure cof all things made and grown'. Their main message is 'the lighter, the better', which follows on from Richard Buckminster Fuller's dictum of 'more with less'. This is the kind of technological approach which should be reflected in the concept of a space center.

In architecture, lightness is not all about weight but also appearance.

3.3 FORM

In Architecture, form not only strongly influences the external visual appearance of the building but also affects the interior space; the two cannot be divided.

We are fortunate to be living in an age of advanced technology which allows us to design and construct much more sophisticated forms than ever before but we cannot compete with nature which still provides the ultimate source for our inspirations. We are only now beginning to learn about the remarkable geometry and proportions that exist in our natural surroundings. It is fascinating to read Ian Stewarts' book, *Natural Numbers* how often spiral forms and the Fibonacci series (an infinite set of numbers in which each number is a sum of the previous two) occur. The

magnified view of the fly's eye, for example shows how a dome can be constructed of similar elements in much the same way as a geodesic structure. The fluid form of sand dunes and wave patterns offer a rhythmic beauty which surpasses most human constructions.

Buildings, by their very nature, tend to be static, a condition hitherto reinforced by their architecture. The built environment is dominated by ordered and rectilinear forms, in clear contrast to the array of diverse shapes that exist in nature. In a sense, the rigor of the orthogonal is alien in the world and subverts the natural order. A strand of contemporary architecture is gradually emerging from this tyranny of form. Based on geometry that goes beyond that of rectilinear relationships, it exploits the visual dynamism of forms that evoke movement. A space centre should reflect this and thus signify a break with the conservatism of the past and herald the dawn of the new age for mankind.

Order comes from geometry but we can be liberated from that of the box by those geometries that exist everywhere in nature – related to curves, angles and patterns. Neither does rectilinear architecture need to be devoid of movement; rather the transition from point to line to plane to volume must be more informed than to lead every time to a box-like form. To the human being, next in line to a sense of consciousness is a sense of movement and visual movement

in buildings is shaped by geometry, and whether it is through a sequence of interrelated planes defining spaces or via the line of a curve, the architect has the vocabulary to express it. We live in an age of high mobility brought about principally by the development of transport and communications which has allowed mankind to venture beyond the surface of our planet. Beside the static conditions of buildings, the rest of the built environment revolves around the various means of enabling movement. In this sense, we are, compared to previous eras, hyper-mobile and, as constant movement has become increasingly possible, so our appetite for change has enlarged.

In Architecture, it is difficult to identify movement as a powerful guiding force or influence, except perhaps, for limited periods and as isolated incidents. In the work of Bromini and other Baroque architects, for example, there is an almost riotous sense of movement and Gothic ecclesiastical architecture possesses a strong sense of upwards movement.

To an architect, the manifestation of both movement and geometry is the manifestation of many considerations, but it is interesting to consider first the cognitive idea of design. Forming ideas follows in part a structured pattern that is

evolved through training and experience; the other part is intuitive and is a function of how the mind works.

Considering the structured pattern, firstly it starts with an analysis of the brief and the formulation in the mind of what is being asked. On an objective level, this involves the accumulation from all the various sources of hard information about the project – through site visits and conversations and or briefings by the client. From this it is possible to define the main options for laying out the principal spaces. Already a series of coded diagrams can be constructed that although simplistic, contain coded information not only about the basic geometry of space that would arise but how people will move through them. Immediately directional issues come into play, the vistas and basic patterns of anticipated movement through the building. In order for the project to be successful, the essence of a clear diagram must be kept.

3.4 STRUCTURE

Buildings are usually thought of as being static constructions but they do not have to be. They should be designed to be more responsive and to interact with their occupants, especially a building like a space centre which

should represent mankind's technological progress. The building envelope could be more responsive and instead of relying on 'mass' for protection against the elements, it would make more sense to use a series of lightweight layers which would deal with thermal performance, shading, wind deflection and even power generation.

The technology is now available to create more intelligent buildings. It is theoretically possible to achieve not only zero heat loss / gain through a buildings skin but also to collect heat from within the layers and use it to cool the interior of the structure. Curtain walling has come a long way since the single glazed extruded aluminium systems of the 1950's. Arthur C. Clarke once observed that 'any sufficiently advanced technology is indistinguishable from magic'.

The 'active glass wall' at Explore-at-Bristol space and science centre is an example of what can now be achieved by modern architects. In an attempt to create a constantly changing façade to the street frontages, the architects included a number of intelligent glass systems combined with digital art and multiple light sources connected to a sophisticated control system. The façade contains various systems including electrophorretic glass which changes from

transparent to opaque, thermochromic films which are heat sensitive with a visible reaction to changes in temperature etc.

The intuitive part of the process involves reading between the lines. As the architect is looking how to join or arrange the series of spaces, the story about the building is unfolding in the architects mind. Intuition comes into play many times as possibilities emerge on how to arrange things. It is possible to see in the minds eye, the character and shape of three dimensional spaces. Order comes out of this chaos as spaces are organized by the sense of movement. This may simply be a vision of how people will move around or may take account of more psychological aspects.

Inextricably linked to both movement and geometry is another aspect of life; the growth of living forms. Both flora and fauna exhibit patterns and structural arrangements evolved over time, which enable growth and provide the strength to defy the forces acting on them. Even the planets and stars in space move in wonderful patterns which can give inspiration to any architect. One of the most symbolic forms in space is the spiral of a galaxy with a black hole in the centre surrounded by countless stars, many having their own system of planets in orbit, like the sun.

Spirals can hold a considerable fascination. They have been extensively explored in architecture over the years, from the Capital Scroll of the Ionic column to Durers' spiral made up of a series of arcs. This later is really only an approximation of a spiral but nevertheless can work as prescribing the form of the Golden section or following the Golden ratio.

The thermal performance of a building is greatly improved if the glazed areas are protected from direct sunlight, but this does not mean that fixed sun shading devices are necessary during other times. Shading devices can be folded away and extended automatically only when required or can be built into the glazing system. One of the earliest examples of this was at the US Pavilion at Expo '67, in which segmental shading devices automatically opened up on the inside of the transparent geodesic dome when the sun came out. Unfortunately the technology was not quite up to the aspirations of the designer and there were mechanical problems which marred its performance, but the concept was extremely innovative and ahead of its time. Jean Nouvel progressed this idea further at the Arab Institute in Paris, with integral solar-activated-camera-lens-type screening to the glazing system. Solar cell activated shading devices are no longer cutting edge technology and are easy to specify, in

fact this technology has advanced so fast, it may have exceeded peoples expectations. Unfortunately, too many architects are still designing conventional buildings which replicate past styles rather than looking for innovative solutions.

In this aspect of architecture, as with other aspects of life, there are many lessons to be learnt from nature. For example, the Hibiscus flower opens up during the day but closes at night to preserve energy and the Sunflower tracks the sun throughout the day. Solar collectors can be designed to follow the sun and now that photovoltaic cells are more efficient, it can make commercial sense to incorporate them into our building structures. The generation of solar power is good for the environment because it is pollution free, it can relieve from us the vagaries of the unreliable public power supply and reflects the technologies mankind will need to survive in space. It seems particularly relevant to use photovoltaic shading devices because the dual role of providing shading and collecting energy from the sun helps justify the expenditure.

Sustainability is one of the main issues of our time. Low energy solutions can be found with natural ventilation systems, which save on maintenance and running costs. This

doesn’t mean our architecture is primitive or low tech. The British Space Centre in Leicester has vents at the top of the 42 metre rocket tower, which automatically open in hot weather releasing hot air from the top of the tower and pulling cooler air into lower parts of the building. This elegant solution obviates the need for any mechanical ventilation plant or ducting.

There is much to learn about structural systems and how they work in nature, for in nature economy of means is inevitably a priority: the shape of bone structures for example, clearly follows the patterns of stresses applied to them, just as the skeleton works in conjunction with the tension members of muscles and tendons. The remarkable structure of the beehive sets a precedent for lightweight honeycomb structures and parabolic curves occur consistently in plant forms, but even more basic is the geometric code of life itself in the form of the double helix of DNA. For inspiration, we must look at nature, where all the most beautiful plants and flowers possess a quality of delicacy and lightness.

3.5 MATERIALS

The study of materials and the possibilities for their innovative use plays an important part in the development of architecture. Understanding the properties and performance of materials is essential to achieving the right design and specification. This is relatively easy, with conventional building materials because there are so many precedents, but new materials provide more of a challenge and with it the opportunity for innovation.

In addition to more conventional materials in common use in buildings today, such as stone, concrete, steel and glass etc, there is now an almost infinite supply of new and wonderful materials that architects all over the world are using in order to achieve buildings that were previously impossible to build, these include materials such as titanium and other lightweight but strong metals, fibre reinforced ceramics, temperature resistant plastics, intelligent walling systems etc.

New products are developed to fulfil a need and although this may not be specifically for the building industry, there may be applications in architecture, therefore architects have to keep an interest in parallel technologies. There are

many opportunities for this form of technology transfer – the Teflon coatings developed by NASA for the space industry are now widely used in fabric membranes to provide a long life durable finish. Similarly, the ‘shot-peening’ process developed in the aircraft industry for creating smooth curves on metal sheeting is now used for other applications. It has been specified for use on all railway stations on the London Underground by the consultant architects.

Composite materials such as carbon fibre are also used in other industries such as boat building and Formula One motor racing but have been slow to take off in the building industry. With their great advantage of a high strength to weight ratio, it is only a mater of time before their use becomes widespread in the construction industry.

Materials science continues to develop and the new area of development is nanotechnology, where the molecular structure of materials is changed to suit the requirements. We know for example, that the molecular structure of carbon, when changed to a spherical geodesic form, becomes more fluid. This new carbon molecule, C60, has been named a ‘Fullerine’ or ‘Bucky ball’ after Buckminster Fuller. With the progress of this kind of technology, it will not be long before we are able to specify the performance of materials

we want to use in construction instead of being constricted to the use of known materials.

Adriaan Beukers, in his book *Lightness*, says, “The most important thing to do when choosing a material for a certain function is keep an open mind.” But then, this could be said to apply to most things in architecture.

4.0 CHAPTER FOUR

THE CASE STUDIES

This chapter intends to assess some Space Centres in various parts of the world, despite the lack of an existing example in Nigeria. These buildings are studied with the aim of understanding the design approach chosen by the architects of these buildings and understanding the fundamental requirements of theses structures, their merits as well as demerits, if any.

Basic requirements for case studies will include floor plans, elevations and sections where available. Other details such as structural systems analysis etc. will also be very useful.

4.1 FACTORS AFFECTING THE CHOICE OF CASE STUDIES.

The research will endeavour to study the sites, the clients' brief, general descriptions which will include the types of spaces required, their inter-relationships and the actual populations designed for.

The Space Centres and Planetarium shall be analysed within the context of their own existence, bearing in mind the solutions in this country due to climatic, cultural and other environmental differences.

The idea is to use the case studies as guides in the process of evolving a workable and acceptable solution for the study area.

4.2 THE U.K. NATIONAL SPACE CENTRE, LEICESTER.

CLIENT: THE MILLENIUM COMMISION

ARCHITECTS: NICHOLAS GRIMSHAW



SITE: The building is located approximately two miles north of the Leicester city centre and midway between Leicester's central and outer ring roads. The site is located along the banks of the river Soar and used to contain obsolete sewage and storm water tanks.

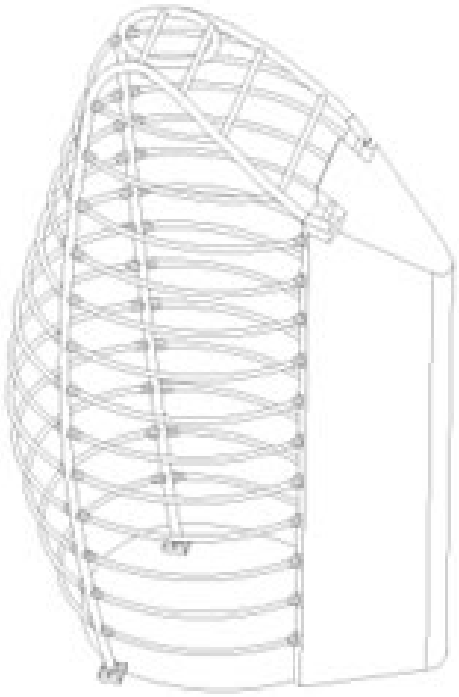
PLATE 4.11. The UK National Space Centre



FIGURE 4.1 Diagram for the layout of the UK National Space Centre, Leicester.

GENERAL DESCRIPTION: Most of the Space Centre is just a box, sunk into the ground. Its flat roof is broken only by the shallow dome of a planetarium beneath.

The ‘rocket tower’ consists of a squat, curvaceous tower rising 140 feet from one corner of the box and facing westwards. Wheelchair access is provided to all parts of the building and the ‘space theatre’ has an induction loop for those with hearing disabilities.





PLATES 4.12 and 4.13. The UK National Space Centre

CONSTRUCTION: The main structure is clad in perforated steel sheets and the ‘rocket tower’ consists of a skeletal frame of steel hoops , covered with inflated bolsters of a special translucent foil which is dotted with tiny metal discs to reflect the sun and thus reduce heat gain by the tower.

Several “decks”, connected by a series of staircases, are placed at various heights in the tower. To allow easier access during replenishment of large exhibits the side of the tower can be partly detached.

MERITS:



I. Use of Modern materials and technologies in the construction.
II. Use of air vents in Rocket Tower to provide natural ventilation.
III. Adequate parking facilities
IV. Presence of interactive visitor exhibits.
V. Adequate visitor facilities including restaurant, bar, shop, etc.

DEMERITS:

I. Poor natural ventilation and lack of natural lighting in exhibition areas.
II. Lack of outdoor activity area.
III. Poor site location, far from city centre with poor access by public transport.



PLATES 4.14 and 4.15. The UK National Space Centre

4.3 THE TYCHO BRAHE PLANETARIUM, COPENHAGEN,

CLIENT: IMAX TYCHO BRAHE PLANETARIUM

ARCHITECTS: MAA KNUD MUNK

SITE: The planetarium is located at the old salt store building area by the lake Jorgen, in the centre of Copenhagen. The existing salt store building which had also served as a music place, was demolished and its foundations removed to make way for the new planetarium.

GENERAL DESCRIPTION: The Planetarium was inaugurated on October 31, 1989, and opened on November 1, 1989.
The laying of the foundation stone took place on February 22, 1988.



PLATE 4.16. The Tycho Brahe Planetarium

This date was not chosen by coincidence. Exactly on this day two planets, Mars and Uranus, were in a rare close conjunction, i.e. observed from the Earth they were very close to each other in the sky.



The name of the planet Uranus originates from "Uranos" - the Greek word for God of the sky. Therefore the foundation behind the Planetarium is called the Urania Foundation.

PLATE 4.17. The Tycho Brahe Planetarium

The planet Mars played a major part in the astronomer Tycho Brahe's work with determination of positions - a work which became of great importance to the astronomy for many centuries.

The foundation stone, which was placed in the floor in the middle of the big cylinder building, bears the inscription: *22. February 1988. Tycho Brahe Planetarium. 2447214,37. Non Haberi Sed Esse. This building has been founded by Bodil & Helge Pedersen for the purpose of encouraging the knowledge of and the understanding of the surrounding universe.*

The long series of numbers is the so called Julian calender, which is used within astronomy because it is universal. The latin inscription means: "Not to think, but to be" - The motto of Tycho Brahe.



PLATE 4.18. Inside the Tycho Brahe Planetarium

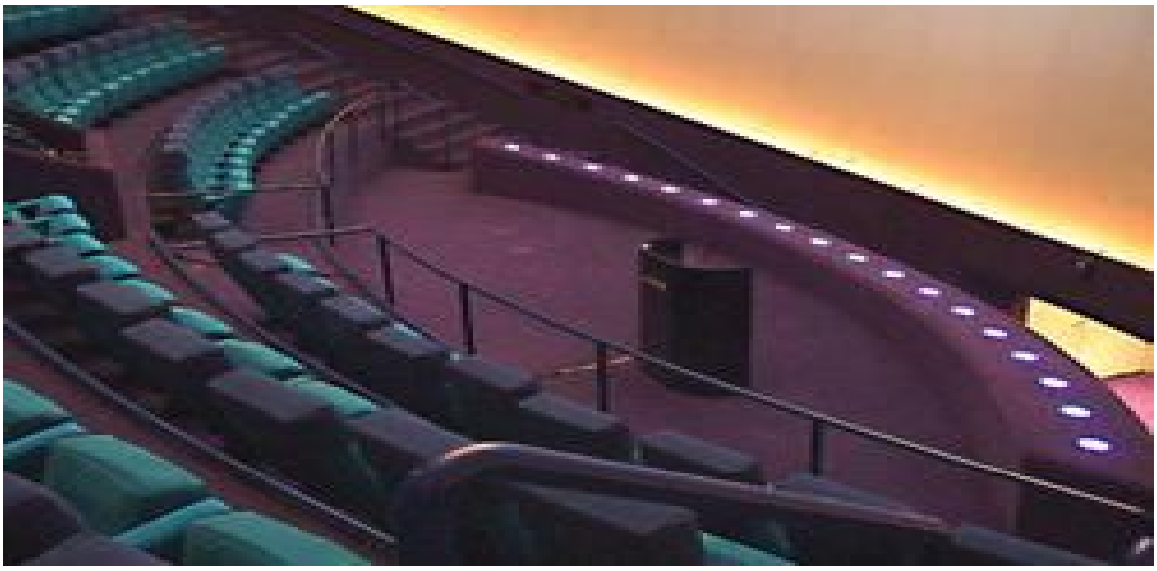


PLATE 4.19. Inside the Tycho Brahe Planetarium

CONSTRUCTION: The ceremony of raising the rooftree was held on Friday, October 14, 1988. The highest point of the building - the oblique cylinder (with the Space Theatre itself) had been reached. The highest point is about 38 metres above street level, similar to a 12 storied building.
The Space Theatre is the very heart of the building. On the 1000 m² dome shaped screen one can experience the worlds biggest film format - the spectacular IMAX films.
And the Star projector can present the night sky as beautiful and bright as if you were sitting on a hillside, far from the city lights.
There are 258 seats in the Space Theatre.



PLATE 4.2. Inside the Tycho Brahe Planetarium

MERITS:

I. Very good location, close to the city centre.

II. Good library facilities, open to the public.

III. Very interesting design with a good spatial layout.

DEMERITS:

I. Limited exhibition spaces.

II. Poor parking facilities

III. Excessive reliance on artificial lighting.

IV. No outdoor facilities.

THE WELLCOME WING, LONDON SCIENCE MUSEUM.

CLIENT: THE LONDON SCIENCE MUSEUM

ARCHITECTS: WILKINSON EYRE / MACORMAC, JAMIESON AND PRICHARD.

SITE: The Wellcome Wing of the Science Museum is a major extension to one of London's best loved institutions. It is quite unlike the Victorian building from which it projects into the backlands of South Kensington, in the South West area of London city centre.

GENERAL DESCRIPTION: The Wellcome wing, of the London Science Museum was generated with a design and build contract, under which control was passed from architects to builder on completion of working drawings. Architect, Richard MacCormac's basic idea was essentially simple. He wanted to create a 'theatre of science', filled with 'lumiere mysterieuse' in which visitors and what they look at could both be actors. You approach through a relatively small opening from the lofty space of the gallery redesigned by Chris Wilkinson and his team.

A Deep blue light beckons you in past the orange portal. A vast and mysterious space is revealed, dark and blue, with strong accents of white or warm light over particular exhibits or events. The drama of progress into Wellcome is enhanced by a great curving canopy which sweeps upwards into the space as you move forward and reveals its huge size (exaggerated perhaps by the lumiere mysterieuse).



PLATE 4.21. Inside the The Wellcome Wing.

Three exhibition terraces hover in the space. Each is rather narrower than the one below, so that the front edges of the terraces echo the curve of the great canopy which faces them, further emphasizing the height of the place. A long thin escalator rises to the right, piercing the curved canopy. To the right of the orange portal are the stairs and lifts which get you up to the first terrace.



PLATE 4.22. Inside the The Wellcome Wing.

You are delivered by both to a quite narrow corridor in which a brightly lit almost-industrial metal floor hangs between two dark blue walls and delivers you to the entrance to the terrace. Similar arrangements are created for the upper terraces, and the whole makes a tall, almost Piranesian backstage for the theatrical exhibition terraces which span across the central volume to another vertical circulation bank, similar to the one you have ascended in, but without the lifts.

CONSTRUCTION: From below, the IMAX theatre, the terraces and their contents seem to float in blue space. The illusion is partly generated by the fact that the trusses, which form the structure of the terrace plates, bear onto steel brackets. Concrete columns in the side walls of the main volume carry these pivoted steel brackets, the outer ends of which are restrained by vertical ties in the external walls of the whole building. By effectively cutting down the span of the terrace plates, their depth is reduced, further adding to the weightless, soaring atmosphere.
Yet the device which makes the main space so ethereal is the west wall, 30m square, and designed to transmute day and sunlight into the luminous blue which transfuses the whole place. Much research went into creating a sandwich, in

which the inner layer is of 8mm blue glass, and the outer 6mm of clear. Between the two are encapsulated fixed, highly polished aluminium louvres. By itself, this sandwich would not reduce the brightest sunlight nearly enough, and a layer of perforated aluminium panels, arranged on the same grid as the glass, is set 1.5m further out. Between the two is a steel structure suspended from concrete services towers which terminate the vertical circulation volumes on each side of the composition. The width of the hung trusses allows walkways for cleaning and replacing the glass.

The total effect of the blue wall is to mute and control whatever happens outside but it allows a sense of season, time of day and weather, unlike many galleries.



PLATE 4.23. Inside the The Wellcome Wing.

Blueness is complemented by the treatment of the side walls, where taut fabric is bathed in artificial light similar to what comes in from the sky through the west window. Luminance of interior surfaces can of course be changed. This is but one of many ways in which the atmosphere can be altered.

MERITS:

DEMERITS:

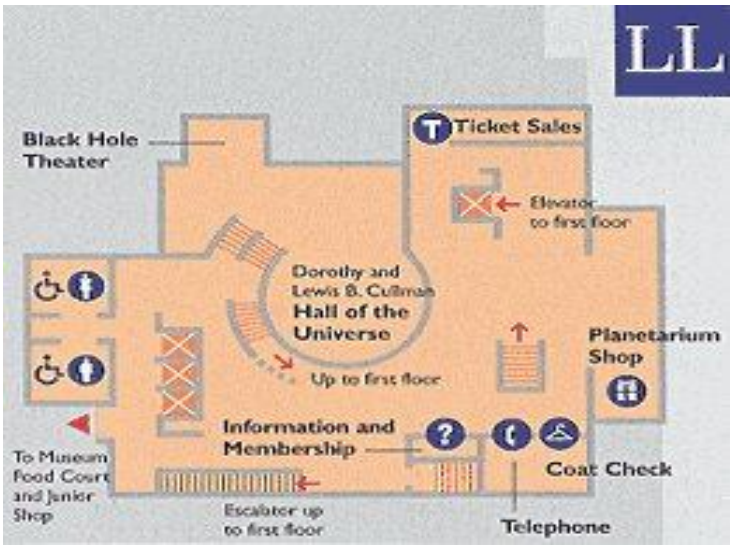
4.5 THE ROSE CENTER, NEW YORK.

CLIENT: THE AMERICAN MUSEUM OF NATURAL HISTORY.

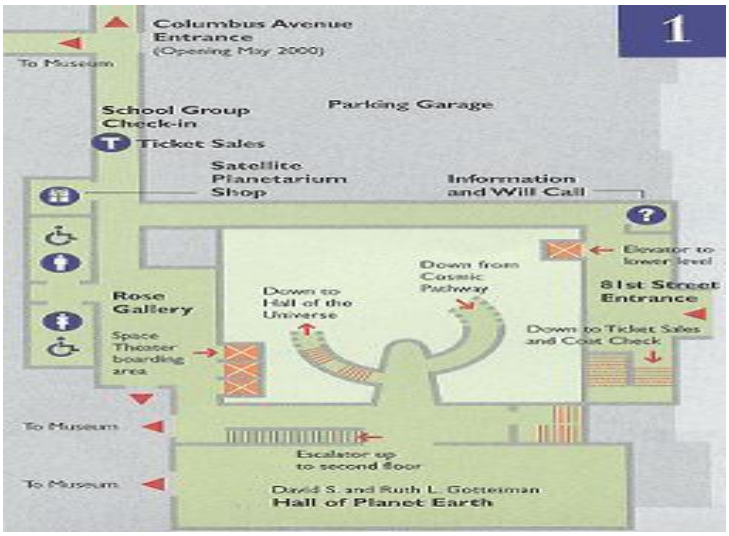
ARCHITECTS: POLSHEK AND PARTNERS

SITE: The planetarium is located on the north side of the American Museum of Natural History in New York at Central Park and 79th street.

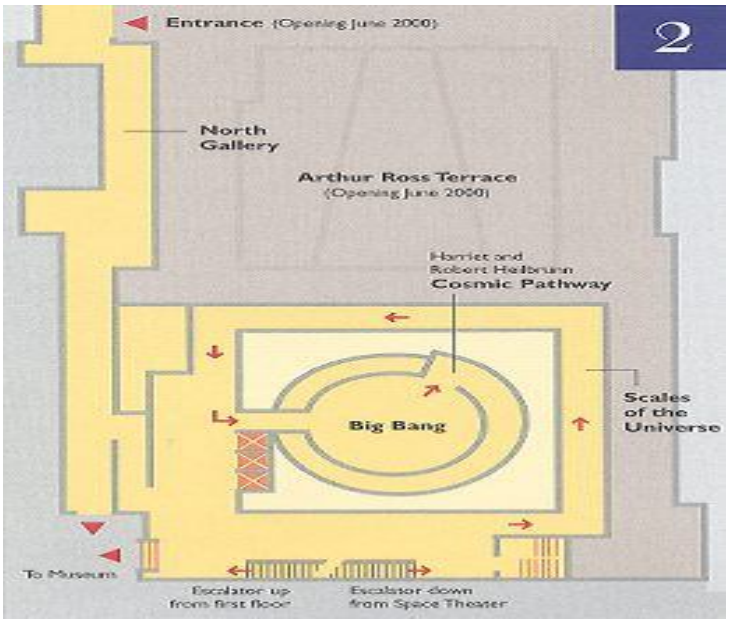
It was completed in the year 2000 and replaced the old Hayden planetarium which formerly occupied the site and was built in 1935.



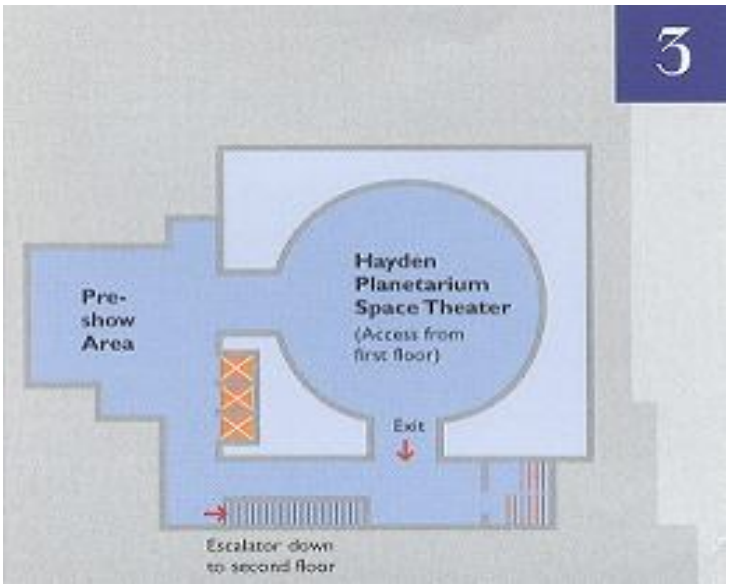
BASEMENT LEVEL FLOOR PLAN



GROUND FLOOR PLAN



FIRST FLOOR PLAN



SECOND FLOOR PLAN

GENERAL DESCRIPTION: The design concept is of a sphere seemingly ‘floating’ within a transparent box with a cantilevered spiral ramp enclosing the sphere.

The principle architect, James Stewart Polshek describes the building as a “cosmic cathedral” in which the spatial experience will awe and inspire visitors with an understanding of the universe and the power of scientific enquiry.

The centrepiece of the Rose Center is the 2,000 ton sphere that houses the New Hayden Planetarium Space Theatre. The arched entranceway has the same radius as the theatre, forty-three-and-a-half-feet. Adjacent to the planetarium structure is a parking structure for 300 vehicles topped with a planted terrace and upper level access to the planetarium. The lowest

level of the Rose Center contains the Cullman Hall of the Universe, where a thematically linked sequence of exhibits reunites the new building with the old and heightens the public's understanding of astronomy and its connection to the other natural sciences.





PLATES 4.24 and 4.25.(above and right) and 4.26 (below) External views of the Rose Center



Traditional columns are replaced by

2-way roof trusses and unique wall trusses.





A vertical and horizotal tension truss system holds the 736 panes of glass in place in the first curtain wall of its magnitude in the United States.





PLATES 4.27, 4.28, 4.29 and 4.3 (above) and 4.31 (below).

Inside the Rose Center.



A spiral ramp called the heilbrunn cosmic pathway encirles the lower portion of the planetarium

CONSTRUCTION:The 87-foot diameter sphere, clad in white aluminium panels, is supported by three pairs of 60 foot long, tapered steel legs. The legs also anchor a spiralling ramp that connects one of the theatres inside the globe to the first level of the building.

Within the Space Theatre (which still carries the Hayden Planetarium name, although it is now part of the Rose Center), visitors sit in high-backed auditorium chairs with headrests and look up to the hemispheric dome. Made of off-white coloured, perforated aluminium panels, the dome serves as a scrim. The dome is several feet in from the outer surface of the sphere, and the space between the two surfaces-containing scaffolding and catwalks for maintenance of equipment-has a network of conduit enclosing miles of power and communications cabling.

Other project elements are the new Columbus Avenue entrance, expanded restaurant and retail facilities and an educational resource centre.

MERITS:

I. Located in an excellent location in the middle of town with good access by public transport.

II. Good natural lighting through glass curtain wall.

DEMERITS:

I. Poor facilities for disabled visitors.

II. Poor natural ventilation.

III. Inadequate parking facilities.

IV. Minimal provision for outdoor recreation.

4.6 THE CAPE TOWN PLANETARIUM.

CLIENT: IZIKO MUSEUMS OF CAPE TOWN, SOUTH AFRICA.

ARCHITECT:

SITE: The building is located at 25, Queen Victoria Street, Cape Town and is part of the South African Museum building.

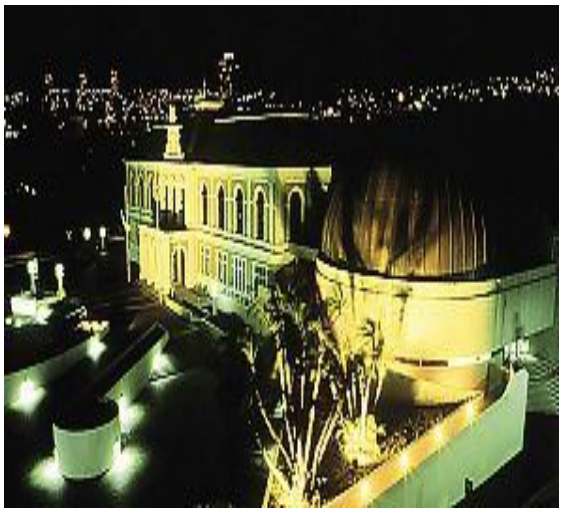
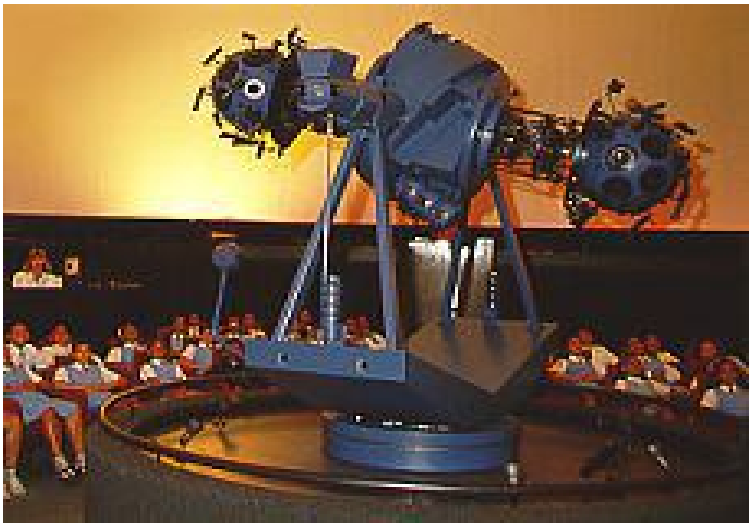


PLATE 4.32. The Cape Town Planetarium.

GENERAL DESCRIPTION: Cape Town's Planetarium was part of a R20 million extension of the South African Museum and was completed in 1987.





PLATES 4.33 and 4.34. The Star Projector at The Cape Town Planetarium

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PLATE 4.35. The Cape Town Planetarium.

CONSTRUCTION:

At the South African Museum Planetarium in Cape Town, Anthony Fairall also uses a Silicon Graphics workstation to manipulate data into all-sky images-this a pie-wedge section of the radio sky and this a pie-wedge section of the distribution of galaxies out to 250 million light years as seen from the southern hemisphere. Galaxies are color-coded white to blue to indicate distance, and Tony is working on a color-coded version that-when used with chromadepth glasses available from a laser company called Audio-Visual Imagineering-will produce a three-dimensional effect to demonstrate the clumping of galaxies.

MERITS:

I. Connected to Science Museum, popular with tourists.

II. Good location in the suburbs of Cape Town.

DEMERITS:

I. Aging and dilapidated structure.

II. Conservative architecture, uninspiring.

III. Dated equipment.

IV. Lack of outdoor facilities.

4.7 GENERAL OBSERVATIONS.

From the various case studies, the following observations were made.

a. Most of the buildings studied had very poor natural lighting and ventilation systems, although a very good effort was made with the Wellcome Wing of the London science Museum with the ‘blue wall’.
b. The majority of the case studies revealed a lack of multi-functional spaces and flexibility in their designs.
c. Probably, due to their location in temperate regions, most case studies had poor provision for outdoor visitor facilities.

CONCLUSIONS.

An emphasis should be laid on location, site planning, facilities, spatial relationships, construction techniques and materials in line with modern trends to provide an uplifting and inspiring architecture.

CHAPTER FIVE

THE PLANETARIUM

The planetarium, both as a fine instrument and as an institution, has come a long way since 1923 when astronomer Elis Stromgren wrote:

"*Never before was an instrument created which is so instructive as this; never before one so bewitching; and never before did an instrument speak so directly to the beholder. The machine itself is precious and aristocratic... The planetarium is school, theater, and cinema in one classroom under the eternal dome of the sky*."

Today the word planetarium can refer to several things. It can mean a special projection device designed to create indoors the appearance of the stars and planets. It can also apply to the room housing such a device or the building containing that room.

Modern planetariums date back to the 1920's when the first such device was designed by Dr. Walter Bauersfeld and constructed by the Carl Zeiss company for the Deutsches Museum in Munich.

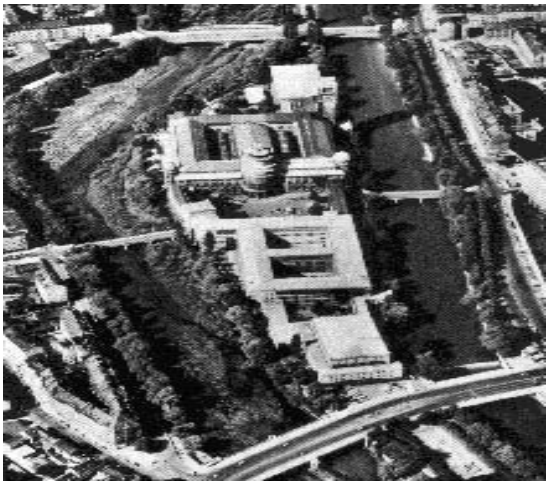


PLATE 5.11 The Deutsches Museum in Munich, site of the first planetarium.

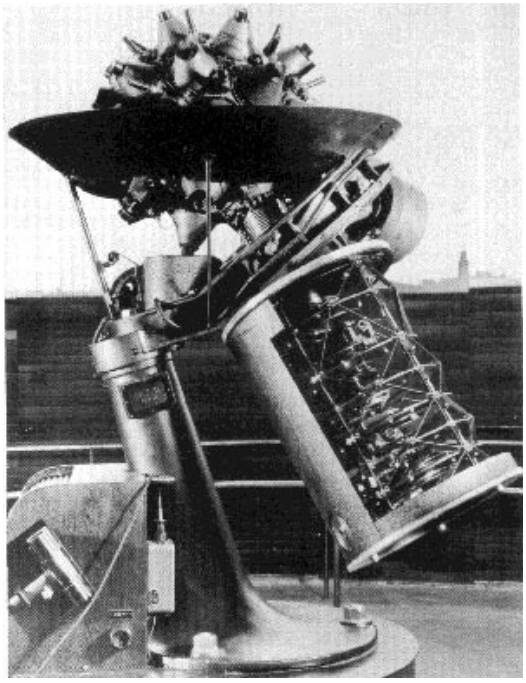


PLATE 5.12 The first planetarium instrument in the Deutsches Museum in Munich, 1923

In the 1930's planetariums started to appear in the major cities of the world, nearly all of them using projectors made in Germany. Most planetarium programs at that time were little more than lecture-demonstrations by an astronomer in the planetarium chamber.

By the 1950's and 60's new planetariums boomed, many of the smaller facilities became possible due to lower priced planetarium projectors made by the American company, Spitz. Spurred on by various space programs, the rate of new planetariums peaked in the late 60's and early 70's but has continued vigorously till date.

In recent years, the design of new planetariums has been marked by sweeping changes and improvements in planetarium technology. Now, most programs in larger planetariums are totally automated, require banks of special effects projectors and feature a variety of state-of-the-art audiovisual equipment. The opportunity for new and innovative planetarium design has never been greater. Just as the technology has changed, so has the potential for new and imaginative
programs. Though most planetariums devote their energies primarily to astronomical shows, it is now possible to present programs on nearly any topic from the inside of atoms to the pyramids of Egypt.

One hundred years ago the frontier of human exploration was at the poles of our earth Today, the new frontiers of human exploration lie far beyond the earth, extend through our solar system, across interstellar space, and reach out to galaxies billions of light years away.



PLATE 5.13 A planetarium display

We can still experience adventures in this realm with old technologies like the printed word. Unlike a hundred years ago, however, we can now simulate these distant environments and let people see what it's really like to be there.

Modern planetariums can be simulated space ships, staffed with knowledgeable tour guides so that the ordinary citizen can explore the wonders of the universe.

WHY BUILD A PLANETARIUM?

Planetariums have been established for a variety of reasons; some of them not always stated. A few have been built solely as useful tools for teaching
celestial navigation. Some came about primarily as memorials to rich and/or famous people. Others were designed as unique attractions to draw visitors to a museum. Still others were intended from their inceptions to serve as multimedia theatres for a wide variety of educational and entertaining programs.



PLATE 5.14 The Big Bang Exhibit at the Rose Center, New York.

Perhaps the best primary reason to establish a planetarium is to provide a community a place where people can enjoy a guided journey of exploration through the vast cosmos to which we all belong. Never before has science known as much
about the universe as we do today. Never before have we acquired new information about the universe as quickly as we do now. Yet, at the same time, never has the general public been so ignorant about even the basic facts of celestial science.
Hence the need for planetariums as front line artillery in the battle for science literacy has never been greater.

The educational role of the planetarium is enhanced by the ability of the stimulating planetarium environment to inspire enthusiasm for science; awe at the marvels of the universe; and new perspectives on our world and civilization.

Many school systems and colleges now use a planetarium in their astronomy courses. While small planetariums find their primary use as teaching devices, the planetariums in museums serve the function of informing an interested audience of the wonders and discoveries of astronomy, from the simple identification of constellations to elaborate, sophisticated multi-media shows demonstrating and explaining concepts which were not even around when Bauersfeld first proudly demonstrated his "Wonder of Jena"; e.g., quasars, pulsars, and black holes. (actually black holes were "invented" about 1913, but no one thought of talking about them in a planetarium!) Modern planetariums have been used for the performance of science fiction plays, musical events, and multi-media shows with light, sound, and live performers.

In this sense a planetarium is of no less cultural importance than a library or museum.

Perhaps the poorest reason to build a planetarium is to make money. Very few, if any, planetariums generate more money than they cost, when all the direct and indirect costs are taken into account. Neither do most libraries nor museums. The point is that these educational and cultural institutions are not, by nature, for-profit businesses - at least not in the

monetary sense. The 'profits' that they generate are more enlightened citizens who live more enriched lives.

To their credit, however, many planetariums can and do recover large portions of their operating expenses from ticket sales, facility rentals, gift shop sales, and financial grants.

FACTORS AFFECTING PLANETARIUM DESIGN

The planetarium is a multimedia room in the proper sense of the word. With its sound and lighting system, video, slides and the star projector system, the spectators are surrounded by a total experience.



PLATE 5.15 A display at the Cape Town Planetarium

The design considerations for a good planetarium include the size of the planetarium, its self defined tasks, the proposed content of its shows as well as the budget available. There are experts who say that a good projector and a well versed operator-narrator are all that are necessary for a good show but this has been contested by others who say that more parameters are involved.

One important question to be answered before designing the planetarium is that of “Who is the target audience?” These may vary from university and college students to tourists to primary and secondary school students to researchers and scientists or just family outings.

Also the projected size of audiences is an important consideration, for example will it host primarily small group shows or large general audiences.



PLATE 5.16

A meteorite exhibit at the Rose Center, New York

Another important consideration is the proposed location of the planetarium and the geographical area expected to be served by it as well as the population of that area. Furthermore, “will the planetarium be used solely for astronomy education or will other multimedia programs also use the space and equipment available?”

Last, but not least, issues of finance and budget including, how the planetarium will be funded, staffed and maintained.

BASIC FACILITIES

Some basic facilities required in a planetarium include the following:

5.31 VISITOR AREAS:

Entrance

Box office / Tickets / Souvenirs

Light Trap

Auditorium / Planetarium Dome

Exhibition area

Observatory

Lecture / Movie theatre

Conference / Seminar room

Library

Café / Restaurant

Visitors Toilets

Provision for disabled users

5.32 SERVICE AREAS:

Projection Dome

Catwalk / Ladder behind Dome

Control Desk

Stage / Platform

Projector Gallery / Projector Booth

Pit for projector lift

Laser room



PLATE 5.17 The Budapest TIT Planetarium

SIZE AND SEATING

Various sizes of planetariums include portable planetariums with an inflatable dome, school based planetariums, medium size (dome diameter 30-50 feet) public planetarium and large public planetarium (dome diameter greater than 50 feet).



PLATE 5.18 The Berlin Planetarium

It takes time to get to know the unique goals, needs and resources of any particular planetarium.

Experience has shown that many costly oversights, shortcomings and outright mistakes in new planetariums could have been averted if adequate studies are carried out before initial designs are made.



PLATE 5.19 The Laupheim Planetarium, Germany



PLATE 5.2 Planetario de la Universidad, Santiago de Chile

Some basic questions that have to be answered at the initial design stage include what size will the interior of the planetarium dome be, in order to function effectively, and if one wants to use the planetarium for things other than planetarium shows (e.g. concerts, live drama, classes, conferences, etc.)?

Another important issue is if the planetarium will be a tilted or level dome as well as what material will the dome be made of (solid plaster, perforated metal) although most modern projection domes (the interior surface of the planetarium) are made of perforated aluminium panels riveted to a rigid framework which is then attached to permanent structure. Perforated metal domes allow sound transmission through the dome, improve theatre acoustics, and contribute to improved air circulation. The material used for the projection dome dictates the reflectivity of the dome surface.

Also, the designer needs to know how high will the spring line (sometimes called the horizon) of the dome be above the theatre floor, as low spring lines help audiences feel that the planetarium experience is around them, while high spring lines give audiences the feeling that the experience is above them.



PLATE 5.21 Heureka Finnish Science Centre, Helsinki-Vantaa

Another important design issue is how much clearance and access will there be behind the projection dome? A permanently fixed walkway (catwalk) located behind the dome allows staff to access the rear of the screen and are usually placed at or near the dome spring line and usually extend a full 360 degrees around the back of the dome. Catwalks may be multi-tiered, or spiral upward to improve access to upper portions of the dome. Revolving, behind-the-dome ladders can achieve the same effect. Catwalks and ladders are optional but should be strongly considered if much rear dome access is anticipated. Other considerations for access behind the dome are if live actors or models are expected to utilise the space behind the dome.

The provision of a Light Trap is also essential. This is a hallway, tunnel or room with a double set of doors through which all audience members enter and exit the planetarium theatre without letting light into the darkened theatre so as to allow entry and exit without disturbing ongoing programs.

The projection dome should have a shelf or space beneath, behind, or in front of the spring line where most special effects projectors are located. This space is known as a cove.

Many older designs have a projection booth or booths for special effects, slide projectors, movie projectors, video projectors, etc, but most new designs have the operator sitting amongst the audience and controlling the exhibition with computers.

Further issues include how many seats will the theatre have and how will those seats be arranged?

The so-called concentric seat arrangement is the most suitable for astronomical presentations. The edge of the dome is the (mathematical) horizon at the same time - the plane of reference for the rising and setting of the celestial

bodies and the planetarium seating is arranged in a circular format where all seats face toward the centre of the room and the centre of the circle formed by the chairs coincides with the centre of the planetarium.

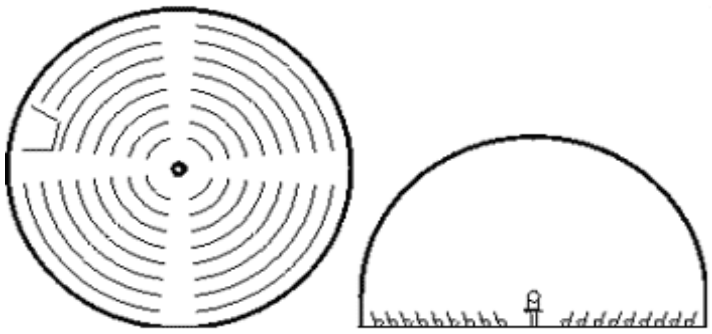


FIGURE 5.1 Diagram for the concentric seating arrangement.

Concentric-conical seating is a similar concentric arrangement with the rows of seats rising from the centre toward the edge of the dome. It is favourable for astronomical presentations and has improved viewing conditions for all seats.

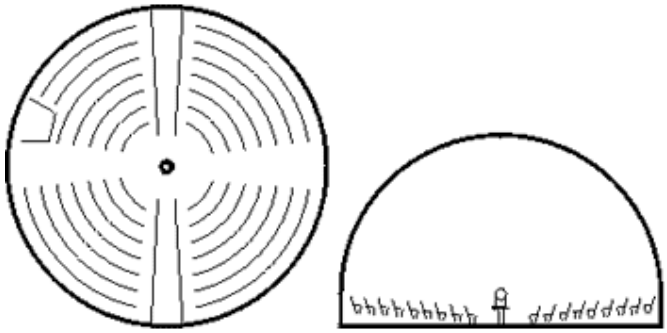


FIGURE 5.2 Diagram for the concentric conical seating arrangement.

But spherical astronomy is not the whole story.
This is where slide and video projections come into play. These are, however, projected in a single direction. There will always be seats where visitors are forced to crane their necks to see properly.
The solution: either the pictures are projected onto two or even three different positions in the dome, or all the seats are aligned in the same direction.

Unidirectional seating is the more common type at present. The audience sits in rows curved in varying degrees such that every seat faces the same part of the dome. The planetarium projector has been provided with a vertical axis to permit the southern sky to be moved to the north and the northern sky to the south, if necessary.

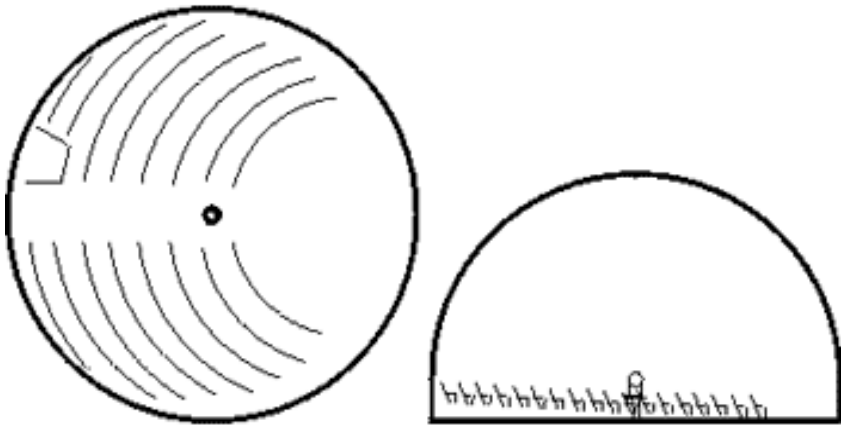


FIGURE 5.3 Diagram for the unidirectional seating arrangement.

However, the audience still has to gaze upward. Seats with high backs are comfortable - but for how long? One solution to the problem seems to be tilting the auditorium and, as a result, the projection dome. The audience sits in much the same way as in an amphitheatre.

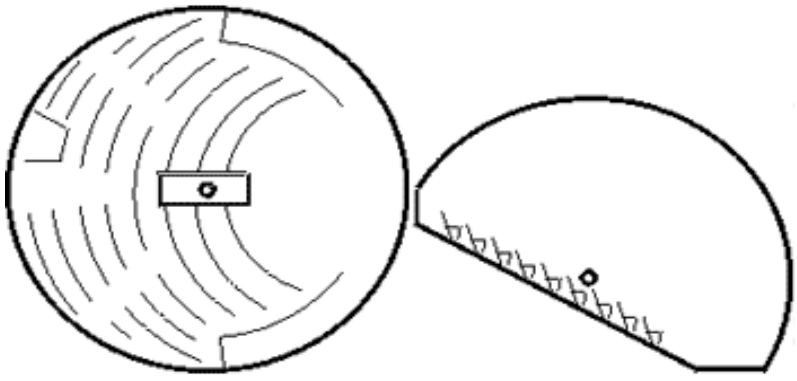


FIGURE 5.4 Diagram for the tilting auditorium arrangement.

The horizon is tilted in the main direction of projection. This is the preferred configuration for large auditoriums where multimedia programs are frequently used with a dome tilt between 10° and 30°.In astronomical terms, tilting makes little sense, and it is even less useful in the case of a small dome aperture (less than 180°).

The seats themselves should be supportive and comfortable. Individual seats are preferred for safety reasons due to the ability of realistic imagery to induce nausea and motion sickness to the viewers.
Many of the new planetariums have seats that are individually 'wired' with sound systems to produce low range frequencies which are otherwise difficult to transmit as well as being provided with controls to allow for interactivity between the viewer and the program being observed. A good example of this is the U.K. National Space Centre at Leicester which runs a planetarium whose seats provide an interactive experience with some of their shows.

The interior walls of the planetarium should reflect the need to reduce reflection of light from external sources but the use of black coloured walls below the spring line and in the light trap is often discouraged due to its psychologically depressing effects on the audience. The reflection of sounds and acoustic properties are also very important in

the planetarium. Experience has shown that it is easier to reduce penetration of extraneous noise into the planetarium chamber than to try to increase the noise levels within the chamber so as to drown outside noise.

Flat floors are preferred wherever possible especially when consideration is made of the safety requirements given the low light levels within the planetarium itself. This is also of advantage for disabled users of the facility. Floors should be carpeted for increased acoustics and light absorption.

TYPE OF PROJECTION SYSTEM

The Projection System or Star Projector refers to the primary source of visual display and imagery within the planetarium.

Factors influencing choice of projection system include dome size and reflectivity, as well as availability and desirability of certain features. Other important factors, especially in our own environment, include reliability and availability of spare parts as well as costs of maintaining the projector system.

The most popular projection system is called an all-sky projection system and it creates a seamless hemispheric image covering the entire

dome surface. These are used to create large scale, high impact environmental scenes or to create backgrounds on which other images are projected. Most commonly, All-skies are created by six different slide projectors with matched lenses. They are positioned beneath the dome spring line
at 60' intervals and project directly across the dome. The seamless effect is achieved through the use of specialized photographic masks, which allow each projected image to cover only 1/6th of the dome and blend the edges of adjacent slides. All-sky images can also be created using one projector with a large fisheye lens located at the centre of the room although this is rarely used.

There are two primary types of all-sky projection systems: real-time and offline (also known as "pre-rendered").

Real-time systems use massive amounts of computer processing power to generate every image "on-the-fly." Offline systems render video images out to a storage medium (hard disk, tape, laserdisc) and then play back as needed. Each type has its own merits, but the larger question of which type of system a planetarium might choose is probably more philosophical or financial in nature, rather than technical. Real-time types have their roots in high-end flight simulator displays. Historically, these Image Generators (IGs) were specifically designed to recreate out-of-cockpit views for pilots, ground warfare, and other military training scenarios. Modern IGs provide a more

general-purpose approach to graphics and can now reproduce wider range of content. Production with real-time systems involves creating 3D graphics models for every object in your "show." These models are then given texture and colour, and are placed in a three-dimensional space - the "world." Over time, objects can move from one place to another, change in size and shape, and fly in and out of the audience's view. In the spirit of flight simulators, the audience's viewpoint can also change over time, allowing for tremendous production freedom and graphic realism.

Offline (pre-rendered) types stem from recent advancements in digital video production and non-linear editing systems. Desktop video production and animation has become very popular in the last several years. Today's systems can provide full professional level capability at a fraction of the cost of yesterday's studio gear. Witness television programs like Star Trek and Babylon 5, along with blockbuster movies like Armageddon and Independence Day; each of these productions used PC-based animation and video editing systems to create visual effects.

Auxiliary and special effects projectors and lasers are also extensively used in modern planetariums to supplement the imagery provided by the primary projection system. It is important that all the projector systems are compatible and work seamlessly with one another. Also,

provision should be made in the design to provide adequate space for the projection systems.

SOUND SYSTEMS

A trip to a planetarium is an audio-video experience and the importance of a good sound system cannot be understated. In the Hayden Planetarium at the Rose Centre in New York, the sound system provides directional sounds and subwoofer speakers installed into each seat give visitors a sense of movement and a sensation of "lift off" at the start of the space journey presentation.

It is important that audio sources in the proposed planetarium be identified (e.g., live voice, tape, film, CD, live music, etc.)? Also important are the qualities should you look for in loudspeakers, the number of loudspeakers needed as well as placement of the loudspeakers.
Other issues are the properties of the audio amplifier and how much audio production will be done in-house? (i.e. what do you need in the way of a sound studio, will there be live concerts or theatre in the planetarium?)

We should not neglect the maintenance concerns of the planetarium audio system and what pieces of audio equipment are vital, desirable or unnecessary. Furthermore, will the audio be digital, analog, or both and

what are the special electrical grounding needs of a planetarium sound system. The placing of microphone jacks is important as is if the planetarium offices/exhibit areas have a P.A. system and which audio equipment, if any, will need to be remotely controlled.

HEATING, VENTILATION AND AIR CONDITIONING.

In our environment, the importance of ventilation and air conditioning is of paramount importance. This is particularly relevant when we are discussing a planetarium, a structure that inherently requires artificial ventilation and air conditioning by its very nature.

Factors to be considered include independent climate control as well as noise and humidity control.

There is a specialized need for the ventilation and air conditioning systems in planetarium theatres to include positive air pressure to keep dust out of the
theatre, as well as increased air filtration to take dust out of the air so projection beams won't be seen, and oversized ducts for silent air flow. Air should also be introduced high and behind the dome, and should be pulled into a return air
plenum" low.

Perforated metal projection domes contribute to improved air circulation. Also important are the cooling needs of the lighting, projectors and other electrical equipment in the planetarium. There must be control of all unwanted sounds in the planetarium from HVAC sources as well as projectors and from outside the planetarium.

SAFETY AND SECURITY

It is important to identify the amount of public access permitted within the planetarium itself and to remove sensitive and delicate equipment from harms way. Also, considering that planetarium shows take place at low light levels, it is important that backup systems including emergency bells, alarms and lights, are provided to help evacuate an audience in case of fire, electric power failure or other emergency situations.

If required, provision should be made for fire doors and/or automatic door closers as well as an adequate number of fire exits. Consideration should be made for the types of fire protection equipment required, either, sprinklers, hand fire extinguishers, Halon gas or a combination. Also care should be noted to the damage that will be done by the fire protection equipment if activated.

The planetarium should have an alarm system that should connect the planetarium theatre console and ticket booth to staff offices and work areas as well as adequate phone and intercom systems.

Where possible, it is ideal to have controlled public access to the planetarium separate or with limited access to the parent institution, in case the services of the planetarium alone are required, an example being a special or evening function.

ELECTRICAL AND MECHANICAL SYSTEMS

It is very important that local standards and requirements are adhered to whenever the design of electrical and mechanical systems is undertaken. Local utilities must be contacted on the issue of Water, Electricity and Telephones. Heating, Ventilation and Air Conditioning standards must also be considered.

Solar energy was immediately considered during the design due to its obvious benefits and the unreliability of the local electricity supply.

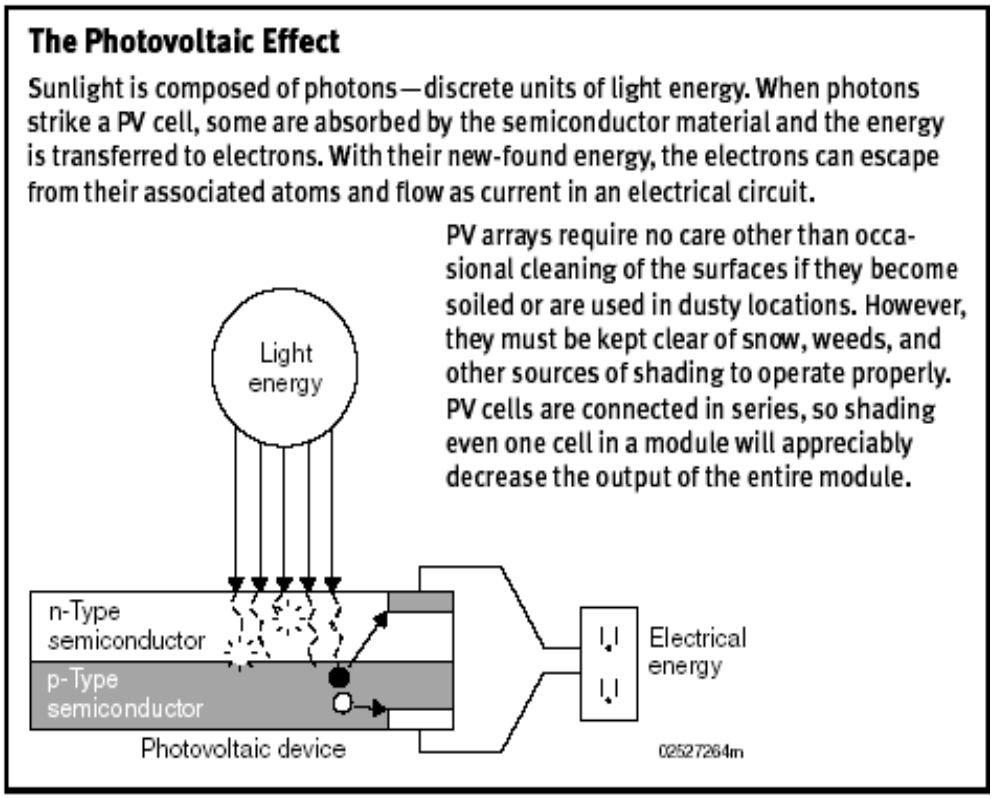
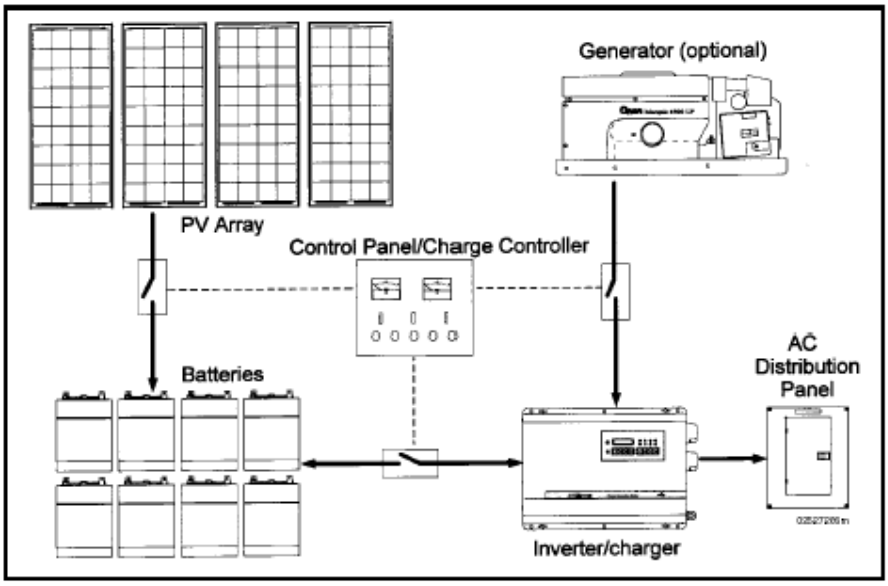


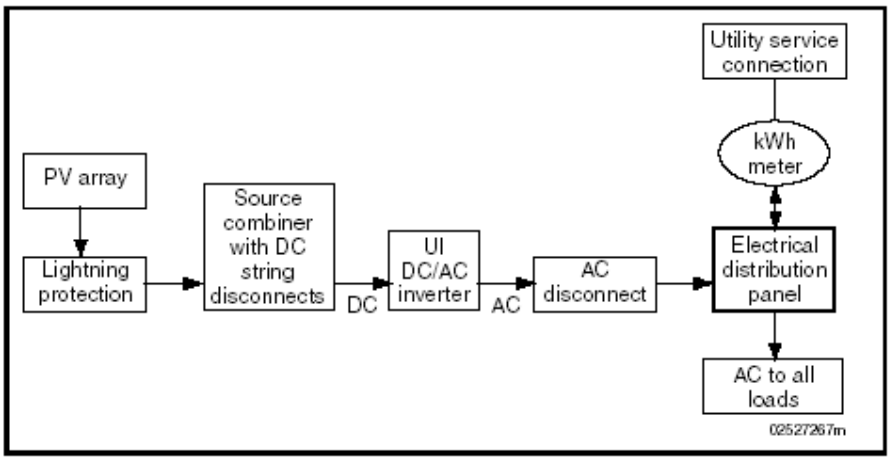
FIGURE 5.5 Diagram for the photovoltaic effect.

Other issues that were considered included how to light the planetarium during shows which typically take place at very low light levels and also how to light the planetarium during cleaning and maintenance as well as the lighting controls to be used. Also relevant was the safety issue of how to light 'exit' signs without spoiling the planetarium shows and whether to have aisle lighting.

It is then important to determine the electrical needs of the building in general and the Planetarium in particular including HVAC systems, internal and external lighting, projectors, sound systems, computers etc.



Schematic of a typical stand-alone PV system



Block diagram of a utility-interactive PV system

FIGURE 5.6 Diagrams for the different photovoltaic systems.

Also to be considered is the type of electrical circuitry and if back-up circuits are required, where will the circuits run and what provision if any should be made for future expansion or increased electrical loads.

6.0 CHAPTER SIX

BRIEF FORMULATION

The basic decision to build a National Space Centre was taken by the Federal Government of Nigeria in May 2001, as a direct result of the National Space Policy in the field of basic space science in order to promote understanding of the universe and how it works. It is important that the proposed building be able to perform the functions for which it is designed and also in itself make a statement about the issues at stake. Achievement of these goals can be attained by a thorough analysis of the functional requirements and spatial organization of the various units and reflecting the interrelated nature of the units in a facility which is a single integrated unit for disseminating information about space science and technology (SST).

6.1 THE SITE

The proposed site for the National Space Centre is at Lugbe District, about 12 kilometres South-West of the Abuja City Gate along the Abuja-Gwagwalada expressway in the Federal Capital Territory (FCT) of Nigeria. The site is bordered on the North-East by the Abuja International Trade Fair Complex and to the South-West by the Lugbe F.H.A. Housing Estate and is directly opposite the road to Piya Hasa village.

The site complies with the Abuja master plan for institutional use and has a total area of about 200 hectares consisting of an undulating plain which is interrupted by some isolated granite rock outcrops and one major hill of granite nature, overlooking the Abuja-Gwagwalada expressway. One major stream at the South-East end of the site creates a prominent valley in that direction. Two other small streams are located at East-Central and North-Western locations on the site. Elevations on the site vary between 405 to 461 metres above sea level.

The climate in the Federal Capital Territory where the proposed site is located records its highest temperatures during the dry season when there are few, if any, clouds. Changes in temperature of as much as 17 degrees centigrade have been recorded between the highest and lowest temperature in a single day. During the rainy season, the maximum temperature is lower due to the dense cloud cover. The diurnal annual range is also much lower, sometimes no more than 7 degrees centigrade, in July and August.

Human sensitivity to temperature is greatly affected by relative humidity. During the dry season, relative humidity may fall to as low as 20 percent in the municipal district of Abuja. Two major air masses dominate the climate of the Federal Capital Territory, these are the Tropical Maritime air mass and the Tropical Continental air mass.

The Tropical Maritime air mass forms over the Atlantic Ocean to the South of the country and it is warm and moist. It moves inland generally in a South-West to North-East direction. The Tropical Continental air mass is developed over the Sahara Desert and is warm and dry. This moves generally from North-East to South-West. The oscillation between these air masses produces the highly seasonal characteristics of weather conditions in the Federal Capital Territory. The Tropical Continental air mass is associated with the dry season while the Tropical Maritime air mass creates the wet season. In June, the Northerly flow of the air component has weakened and only the Southern flow predominates. Being moisture-laden, it brings a lot of rain. In September, the Tropical Continental air mass begins intensify over the Territory and the North-East trade winds become dominant from October to March, bringing with them, the dry, cloudless but dust-laden conditions associated with the harmattan. The dust-laden particles of the harmattan may frequently reduce visibility to within a few hundred metres at night.

6.2 SITE SELECTION CRITERIA

The selected site was chosen primarily because it was selected by the Government of the Federal Republic of Nigeria as the proposed site for the National Space Centre.

Other attractions of the site location include proximity to the gateway to Abuja, the seat of Government and its' location along the busy Abuja-Gwagwalada expressway, probably the most important entry route to Abuja. Most visitors from the South of the country and the Namdi Azikiwe International Airport, Abuja will pass within sight of proposed building. The building will thus serve as a monument to our national aspirations in the field of Space Science and Technology.

Other pluses for the site include its central location on the map of Nigeria, enhancing its accessibility from various parts of the country. Furthermore, physical proximity to various other facilities planned for the site including the proposed Ground Station, Workshops, Laboratories, etc., will also add to the viability of the Centres location.

6.3 DESIGN ANALYSIS

The design criteria deals with the major considerations for the design in respect of actual solutions which are stressed accordingly.

The designed project, the National Space Centre, Abuja is an attempt at the synthesis of all the previously enumerated factors influencing the centre. By using largely interactive exhibits, the National Space Centre is intended to display exhibits as well as the artefacts from mankind's development in space science and technology. The Space Centre has been

made in a very different way from a set of conventional galleries. It has to be very adaptable, as the exhibits will change more rapidly than conventional ones and this dictated the use of large flexible spaces. It had to have very carefully controlled lighting levels, partly because many of the electronic display screens and optical devices need low background luminance.

6.3.1 ACTIVITY ANALYSIS

The main activity of the National Space Centre is promote interest and learning in the field of Space Science and Technology. Thus the activity analysis is directed towards a thorough understanding of all requirements for the activity of communicating concepts and ideas within brief periods of time. The results of this analysis will help in determining subsidiary spatial requirements for other activities related to the Planetarium. Activities easily identifiable with the National Space Centre include exhibitions, seminars and conferences, storage, observatories, workshops, library, archives, souvenir shop, cafeteria, etc. Thus an idea of the types of spaces that will be needed is gradually acquired.

6.3.2 ENVIRONMENTAL ANALYSIS

The environmental analysis is directed towards examining the climatic and external environmental conditions, which

after analysis facilitate a proper response to them during the design synthesis. Therefore all climatic factors come into play and act as guides towards designing the most suitable kind of building structure. Important factors involved in the creation of internal building environments include solar insulation, glare, lighting intensity, humidity, ventilation, temperature and shade, all of which are determined by the climatic conditions of the site. All these factors control the synthesis of the proposed design.

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6.3.3 FUNCTIONALITY

The design of the building should encourage efficient usage as much as possible. This covers areas from ventilation and lighting to provision of adequate facilities for the disabled. It is mainly directed towards the analysis of the functional relationships between spaces and the various factors which govern these relationships, such as proximity, need for adjacency, total separation and so on. The conclusions drawn from this analysis will be some of the major factors used in determining the spatial organisation of the design.

6.3.4. HARMONY

Since it is a part of the environment, an effort must be made to harmonise the building with its environment and exploit

the site potentials to achieve a functional and aesthetically pleasing solution.

Also, the building shall respect design axes indicated on the master plan. Building forms should express the consistent use of a range of harmonious building materials.

6.3.5 LANDSCAPING ANALYSIS

The landscaping analysis undertook an examination of the possible ways and means by which the present environmental situation of the site and the future situation, when the building will be in use, can be properly synthesized with natural and artificial landscaping material so as to produce a more symbiotic environment. The aim therefore is to synthesize all artificial and natural landscaping elements into the building and site layout, in order to achieve an ideal design.

6.3.6 LIGHTING ANALYSIS

This is directed towards examining the natural and artificial lighting requirements of the interior spaces. Natural lighting requirements of interior spaces guide design decisions on the external fenestration arrangement of the building fabric. These requirements have to be, at the same time, synthesized with those of ventilation, solar radiation and shading. In the particular case of the Space Centre, an attempt has been

made to light the interior from above the central courtyard using natural light whose shade has been altered to resemble artificial light, so as to emulate the artificial environment of space. The natural lighting requirements also act as a guide in the design of the artificial lighting arrangements of the interior spaces.

6.3.7 MATERIALS

The analysis of the use of materials in the design scheme is directed towards the maximization of materials' merits in the design. The use of materials in spaces has to synthesized with other design factors such as spatial activities and environmental requirements. The principal qualities of durability, strength and ease of maintenance are synthesized into the other functional requirements which guided their choice. New uses, determined by spatial and functional requirements to which materials could be put, were also analyzed with the view of responding positively to the design objectives.

6.3.8 ORIENTATION

The building should be orientated to face due North and South in order to avoid excessive heat penetration into the interior of the building due to the rising and setting sun. In

unavoidable instances, shading devices shall be used on the East and West façade to reduce heat gain.

Also, the building should be oriented at 45 degrees to the direction of the prevailing winds. This helps to improve the efficiency of natural ventilation by maximising pressure differences on the windward and leeward faces of the building. Prevailing wind directions are North-East and South-West.

6.3.9 STRUCTURAL ANALYSIS

The structure of a building consists basically of floors, walls and roofs. Therefore, in the proposed design, the analysis of the structural components of floor, walls and roofs is taken with the objective of providing positive responses to the structural requirements of the designed spaces. Structural requirements also need to show adequate response to the external and internal environmental conditions in relation to the building envelope and the activity occurring within it. The building structure also aims at synthesizing factors such as economy, durability, construction cost, ease of maintenance and aesthetics. These factors are used as guides during the design decisions on things like building form, structural material and loading requirements.

6.4 THE BRIEF

The brief for the National Space Centre, Abuja was generated from a series of discussions with staff of the National Space Development Research and Development Agency, including the Director General, Dr. Boroffice as well as extensive literary research, the study of various documents and other form of data, architectural proposals, as well case studies of similar projects from different parts of the world which resulted in a thorough understanding of the requirements for the project.

Key elements of the National Space Centre were determined to include the Planetarium, A Visitor Centre, Movie/Lecture Theatre, Observation Facilities and various other inter related facilities as well as support services.

An attempt has thus been made to synthesize all the requirements and provide a workable solution which is both functional and aesthetically pleasing.

TABLE 1. SCHEDULE OF ACCOMMODATION

GROUND FLOOR

ITEM	NAME	FLOOR AREA M2
1	ADMINISTRATION RECEPTION	40

2	BAR	12
3	CAFETERIA	80
4	COURT	460
5	DISPLAYS, EXHIBITS	1250
6	ELECTRICAL + MECHANICAL W/SHOP	24
7	WOOD + CARDBOARD W/SHOP	24
8	GENERAL STORE	18
9	KITCHEN	42
10	KITCHEN STORE	12
11	MULTIMEDIA EDITING	20
12	MULTIMEDIA ARCHIVES	10
13	MULTIMEDIA STUDIO	16
14	OFFICE ACCOUNTANT	15
15	OFFICE DEPUTY DIRECTOR	12
16	OFFICE DIRECTOR	22
17	OFFICE GENERAL	18
18	OFFICE SECRETARY	12
19	OFFICE SECURITY / FIRST AID	12
20	PLANETARIUM UTILITIES	113
21	TOILETS FEMALE	22
22	TOILETS MALE	22
23	UTILITIES ROOM	16

24	MISCELLANEOUS	80
	TOTAL	**2352 m2**

FIRST FLOOR

ITEM	NAME	FLOOR AREA M2
1	DISPLAYS, EXHIBITS	960
2	LIGHT TRAP	80
3	MISCELLANEOUS	60
4	PLANETARIUM	150
5	RECEPTION AREA	122
6	RECEPTION DESK, INFORMATION, TICKETS	30
7	SHOP + STORE	60
8	STORAGE / UTILITIES	60
9	THEATRE	180
10	THEATRE LOBBY	14
11	TOILETS FEMALE	22
12	TOILETS MALE	22
	TOTAL	**1760 m2**

SECOND FLOOR

ITEM	NAME	FLOOR AREA M2
1	DISPLAYS, EXHIBITS	1170
2	MISCELLANEOUS	470
3	OFFICE	16
4	STORAGE / UTILITIES	60
5	TOILETS FEMALE	22
6	TOILETS MALE	22
	TOTAL	**1760 m2**

THIRD FLOOR

ITEM	NAME	FLOOR AREA M2
1	DISPLAYS, EXHIBITS	1186
2	MISCELLANEOUS	470
3	STORAGE / UTILITIES	60
4	TOILETS FEMALE	22
5	TOILETS MALE	22
	TOTAL	**1760 m2**

FOURTH FLOOR

ITEM	NAME	FLOOR AREA M2
1	DISPLAYS, EXHIBITS	1018
2	MISCELLANEOUS	290
3	OBSERVATION DECKS	168
4	STORAGE / UTILITIES	60
5	TOILETS FEMALE	22
6	TOILETS MALE	22
	TOTAL	**1580 m2**

Total floor area = 9212 m2

7.0 CHAPTER SEVEN

THE DESIGN PROPOSAL

This thesis is about designing a building for the dissemination of knowledge about mankind's' technological development especially in the fields of space science and technology.

The building is designed as a single unit of integrated complex functions, which is intended to be an epitome of the term 'universal space'. Thus, the building can be described as enclosing a large single volume of space with relatively long spans and without any major subdivisions. This is a design which is not formal, decorated or mannered, but which derives its aesthetic from a clear expression of its purpose and component parts. It is a design where the demands of function and economy have led to a simplicity of form and construction, but where the basic requirements of enclosure and structure have been extended by design to create a building of quality. The design attempts to provide mental inspiration and physical upliftment for its users. This approach attempts therefore to create a building that will stimulate public enthusiasm for space science and technology.

7.1 THE DESIGN CONCEPT

The layout concept adopted for the design scheme is based on a building with a central core housing the planetarium, which is the major facility of the space centre, surrounded by all other spaces.

The simple concept of circulating around a central courtyard was adopted for the circulation system within the building. This was especially relevant with the concept of providing contact with visually and physically stimulating environments during circulation.

A large central space coupled with the orientation of the building at 45 degrees to the prevailing wind directions also help to reduce humidity and temperature levels within the building.

Control of light is also an important factor in the appreciation of space, and the natural light from above, through the large central dome is more powerful than from vertical planes. Care has been taken when designing the dome to reduce large glazed areas in an attempt to avoid excessive solar gain from sunlight. Spaces which allow penetration of natural light feel more human and friendly due to the warm colour of the light and movement of shadows which animate the space and help with orientation. In the particular case of the National Space Centre however,

the skylight is tinted blue, as are the windows, in order to create a bright but artificial feeling environment, reminiscent of the interior of a spaceship.
The basic building form adopted is that of a circle with a sphere at it's core, similar to the form of a galaxy of stars.

7.2 THE SITE LAYOUT

The final site and building layout evolved as a result of refining the adopted design layout concept. The integration of other site concepts, such as access road, separate parking facilities, circulation route and outdoor facilities resulted in a building that dominates the hilltop where it will be located overlooking one of the main vehicular arteries to Abuja. Positioning of the building with relation to the master plan for the entire proposed Lugbe Space Complex, will ensure that guests also have a good view of the proposed Ground Receiving Station and other facilities proposed for the site from the cafeteria, outdoor amphitheatre, etc. Finally, the outdoor facilities are located to the east of the building where visitors will be shaded during afternoon periods, when the sunshine is most intense, by the building itself.

7.3 SPATIAL ORGANIZATION

Spatial organization is achieved by arranging all facilities around a central core. Also by arranging most ‘behind the scenes’ facilities on the ground floor and having most visitors access the building via the first floor entrance, a good separation has been achieved in a building with a limited ground floor area. Attempts have been made to cater for the various proximity and adjacency needs of the various facilities in the building. Furthermore, the buildings public areas have been designed so that visitors may attend an event in the planetarium or lecture theatre with minimum interaction with the rest of the complex, if so desired, without reducing the integration of those facilities with rest of the complex.

8.0 CHAPTER EIGHT

CONCLUSIONS

The need for a new awareness towards our environment and our place in the universe is now very important for our development as individuals, as a nation and for the human species. We no longer exist in isolation in the universe and our ever expanding horizons of knowledge must be utilised towards improving our prevailing social, cultural and economic situation.

With this philosophy, the field of space science and technology becomes one of improving mankind's conditions of existence in the universe and not an abstract concept as popularly perceived in our society.

Nigeria's first physical venture into space took off on board a Russian Kosmos-3M rocket at 1012 local time (0612 GMT) on the 27th of September 2003 from Plesetsk in northern Russia. The Nigerian satellite - NigeriaSat-1 - is the country's first to go into orbit and forms part of an international network called the Disaster Monitoring Constellation (DMC), which can provide up-to-date information to relief agencies working on the ground.

The DMC help to summon rapid assistance in the event of droughts, earthquakes, fires, and man-made disasters.

The DMC can monitor any point on Earth at least once a day. The satellite can map a 600-kilometre- wide swathe of the Earth's surface at any given point in time.

Experts on international space issues, say the launching of Nigeria's first satellite, which cost an estimated $13,000,000, is an efficient use of public money since Nigeria is a very big country with an important agriculture sector, valuable natural resources, and a fast-growing population. In order for the Nigerian Government to manage all these, either the government decides to place people everywhere to monitor these on the ground, or simply launch one satellite as it has done.

8.1 RESULTS OF SPACE RESEARCH

Some of the results derivable from Nigerian Space Research programme will include the following:

8.1.1 Sustainable Poverty alleviation and Food Security.

Poverty is experienced when majority of the population is without adequate financial resources to cater for their day-to-day needs and this is caused principally by the absence of jobs for this majority of people. On the short and long terms the following resource management systems will be capable

of providing needed jobs to the teeming populace and thus provide sustainable poverty alleviation and food security to the nation.

(a) **Agriculture**.

Through the application of space science research crop performance, crop yield prediction and crop failure prevention can be attained in an intensive agricultural practice that will engage majority of the populace in productive agriculture.

(b) **Land Resources.**

The enhancement of our potentials in oil exploration and exploitation through remote sensing is real and realizable and this sector is known to provide employment for a lot of qualified personnel. In like manner, remote sensing provides a rapid evaluation of our terrain for adequate land use planning that may include strategic and tactical military operations for the various arms of our army.

(c) **Water Resources.**

Through space science application, the quantity, quality of both surface and subsurface water resources of our country can be assessed with a high degree of accuracy for an efficient management. For the coastal zones of the

country especially within the Niger Delta region, the worrisome incidences of saline water intrusion into freshwater aquifers can and have been detected and appropriate measures taken to ameliorate this in the plans for the retrieval systems of potable water within these zones. Within the crystalline basement zones of the country, satellite remote sensing has been successfully used in the location of water boreholes within the quartzitic rocks around Ibadan.

(d) **Ecosystems**

Both land and aquatic ecosystems can be monitored via space satellites for an effective sustainable development.

(e) **Plants**

Plant species in forest systems, ornamental plants as well as medicinal plants can be evaluated, monitored and measured from space satellites for their abundance, progressive depletion and disease states for an efficient and effective national sustainable development.

(f) **Fauna**

Movement patterns of shoals of fish and other marine fauna such as shrimps etc can be detected from space satellites and these communicated to the fishing trawlers for

a rapid and efficient catch system instead of the present laborious and haphazard game of luck that is practiced by the nations fishing companies. In the same way, areas where over-fishing has been practiced leading to the presence of only fingerlings can be avoided and left fallow until the shoals become matured for harvesting again. Just like in fisheries, both domestic and wildlife movements can be detected and these communicated to professional hunters for productive catches. In all these applications the weather forecast prior to fishery and hunting expeditions can be accurately forecast to avoid bad weather during these events.

8.1.2 Space Communication Applications

Space Science and Technology has provided avenues for effective communication systems worldwide but Nigeria remains only a ‘user’ and not a ‘vendor’ in this area leading to the presently observed chaotic telecommunication system in the country. Government therefore needs to use satellite communication system to enhance to:

(i) Accelerate the economic growth rate through affordable telecommunication services. The present state where GSM mobile telecommunication services are beyond the reach of the average Nigerian Civil servant should not be tenable.

The cost of the mobile communication services can be brought down significantly if Nigeria launches her own telecommunication satellite.

(ii) Increase the tele-density of Nigeria within a short time.

(iii) Provide telecommunication services in rural and remote areas of the country

(iv) Provide satellite voice and video- broadcast services (MNET from South Africa is a case example)

(v) Link Nigeria with global information infrastructure.

(vi) Strengthen, develop and extend distance learning educational systems within the country.

(vii) Enhance healthcare delivery system through tele-medicine.

(viii) Provide satellite services which include data imaging, video conferencing, multimedia and global internet access.

8.1.3 Meteorology.

Meteorological weather forecasts in agriculture, civil construction, travels, tourism industry and other aspects of the nation's programmes are some what lacking in depth and coverage. Acquisition of a national space satellite should help in no small measure in this regard.

Existing meteorological stations can be upgraded and more stations established across the nation to assist in the afore-mentioned areas of need.

1.1.4 Defense, National Security and Law Enforcement.

Satellite Space Technology can be applied in the Nations Defense, National Security and Law Enforcement and Government can achieve this through the following ways:

(i) Conflict prevention through pre-emptive actions such as advance communication, early warning system, remote sensing, border delineation, identification of resources and monitoring of movements of suspected perpetrators of various evil plans against the nation.

(ii) Enhancement of Regional Peace Keeping Operations crucial to the ability of our armed forces to protect and maintain our strategic interests regionally and internationally.

(iii) Fight against both national and international crimes such as the global advanced fee fraud (alias '419')

8.1.5 Environmental Management and Pollution Control.

For a country like Nigeria with such a diverse environmental setting, the applications of space science and technology is an advantage in the monitoring of pollution and within each of the various environmental zones. Within the oil producing

areas of the Niger Delta sub-region, oil pollution of the fresh water, marine and land areas can be easily detected as they occur through satellite imageries. Production of solid wastes from urban areas resulting from urban population explosion, development of upland and coastal erosion, flooding and even understanding of the ozone layer depletion and the concomitant global climate change can be addressed through space science and technological development. Measures that can be used to study the control of the above environmental degradations can be easily found after a thorough study of these environmental phenomena.

8.1.6 Promotion of International co-operation

The results of the application of space science and technology by Nigeria will among other things lead to the following:-

(i) Peaceful development and use of space resources for the benefit of Nigerians and mankind

(ii) Bilateral and multilateral cooperation on the basis of mutual benefits and mutual complementarity.

(iii) Building up of the capability for space development of the country.

(iv) Adoption of measures to protect the space environment and space resources in the course of international space cooperation.

(v) Support of the outer space application programmes of the United Nations.

8.1.7 Education and Training

The application of Space Science and Technology will result in the following:-

(i) Development of Nigerian youths as future policy makers to be more aware of the immense socio-economic benefits derivable from present and past developments in science and technology in general and especially in space science and technology.

(ii) Development of a pool of Nigerian scientists that can develop high technology products from space science and technology and thus ensure a sustained technological and industrial development in the country.

(iii) Participation in international programmes in space science and technology and thus ensure co-operation with foreign countries and international groups.

(iv) Assured success and derivable benefits from high technology of the 21st century and beyond.

8.1.8 Commercial Benefits Spin-Offs

The results of the applications of space science and technology to the country will enhance the development of needed computer hardware and software, very large

integrated electronic systems, telecommunications, satellite manufacturing, advances in the development of the life sciences, advanced material resources and satellite launch technology.

These attributes will ensure that Nigeria is no longer only a **'consumer'** nation but a **'provider'** nation. In addition to these, the following benefits will be derivable:-

(i) The nation will be actively engaged in research and development efforts in space science and technology.

(ii) Attraction of foreign industries into the country

(iii) Creation of jobs for the teeming unemployed but brilliant Nigerian youths, thus alleviating poverty and guaranteeing food security for the nation.

(iv) Enhancement of international co-operation that will guarantee peace and security of Nigeria and the world at large.

8.1.9 Hazard Monitoring.

Nigeria is blessed by virtue of not been located within areas considered to be prone to natural disasters such as hurricanes, cyclones and typhoons. However, she is not totally free from hazards such as earth tremors (minor earthquakes) which result from the activities of volcanoes most of which are located outside and a few within her

territorial boundaries. The earth tremors of 1984 in the Ijebu Ode - Ibadan axis of southwestern Nigeria and others which have been reported locally are pointers that we are not entirely free from some of these hazards. Other natural hazards which affect Nigeria are floods, landslides, tidal waves (such as the bi-annual tidal floods of Victoria Island in Lagos), coastal erosion, forest fires, sand storms, dust-storms, locust / insect infestations and other man-made disasters have been recorded. All these natural hazards can be identified from space satellites and advanced warning signals sent out on time to either minimize or entirely mitigate the resultant damages from these events.

8.2 CONCLUSIONS / RECCOMENDATIONS

For a sustainable space science and technology programme for the nation, the recently approved National Policy on Space and Programmes should be strictly adhered to in terms of implementation by creating the National Space Centre. There is a huge benefit to be derived from space science research but these benefits may not be achievable in the long run if certain problems and bottlenecks are not avoided in the national interest. Some of these identified problems and bottlenecks that may hinder sustainable development in

space science and technology are, the will to implement approved policies and programmes, financial constraints, lack of know-how, lack of interest on the part of government, administrative incompetence leading to bottlenecks, lack of continuity in government projects consequent upon changes in leadership and outright sabotage.

8.3 RESEARCH DIRECTIONS

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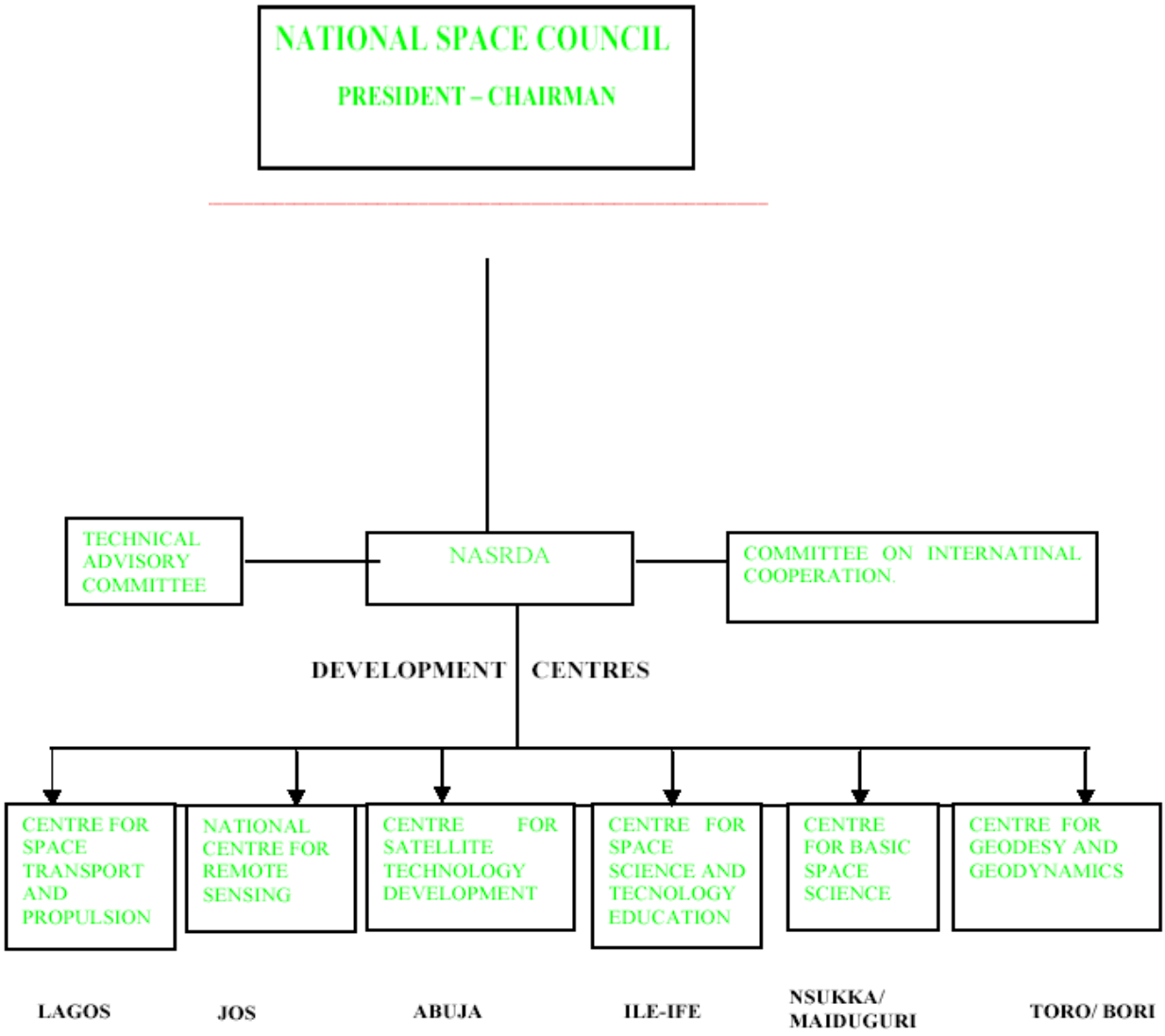
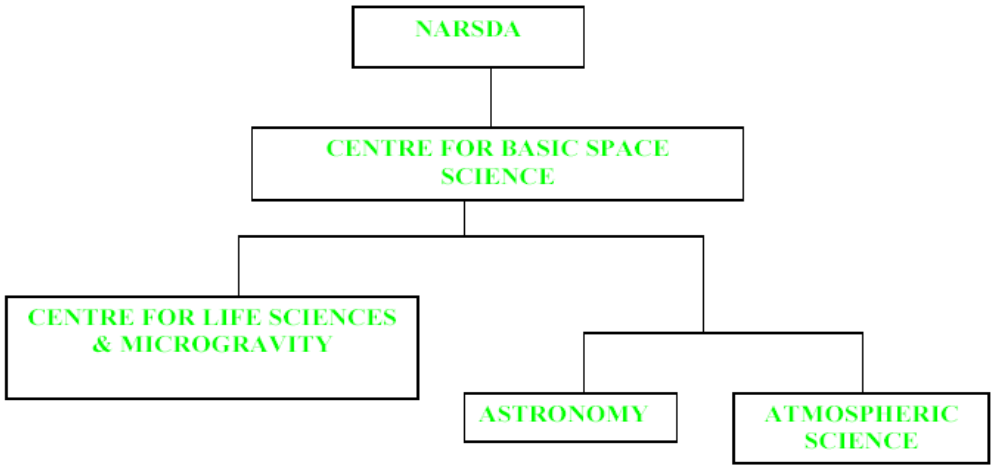
All great architecture is a marriage of technique and purpose, but in much recent architecture, built and un-built, technique overshadows purpose.

Today our facility with making form is unprecedented, yet the most sophisticated methods are irrelevant if our intentions are misdirected. If the task of architecture is to create exotic forms, eventually we may find that our tools will overtake us in this ability. Our aim must be to provide meaningful, humane places and we must be vigilant in pursuing this goal, or the future of architecture may not need us.

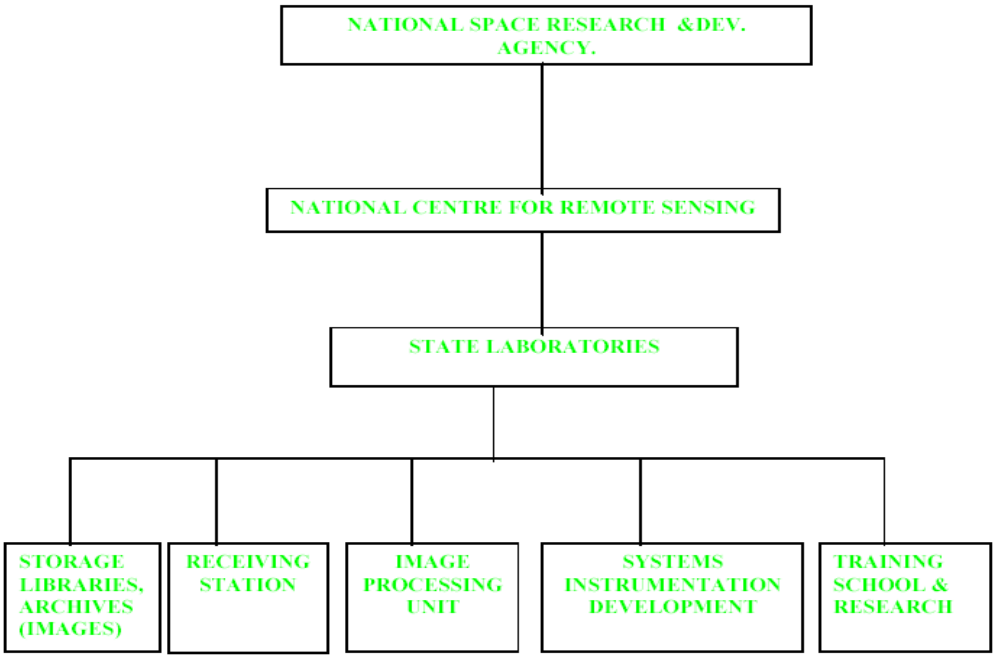
APPENDIX



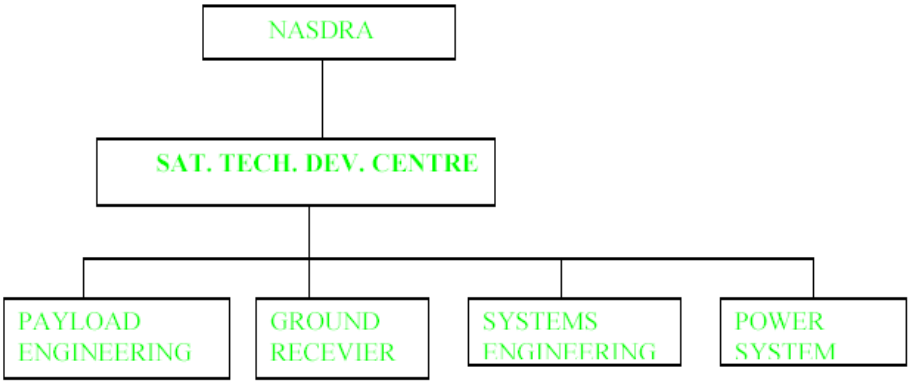
Appendix 1. Organogram for the National Space Programme



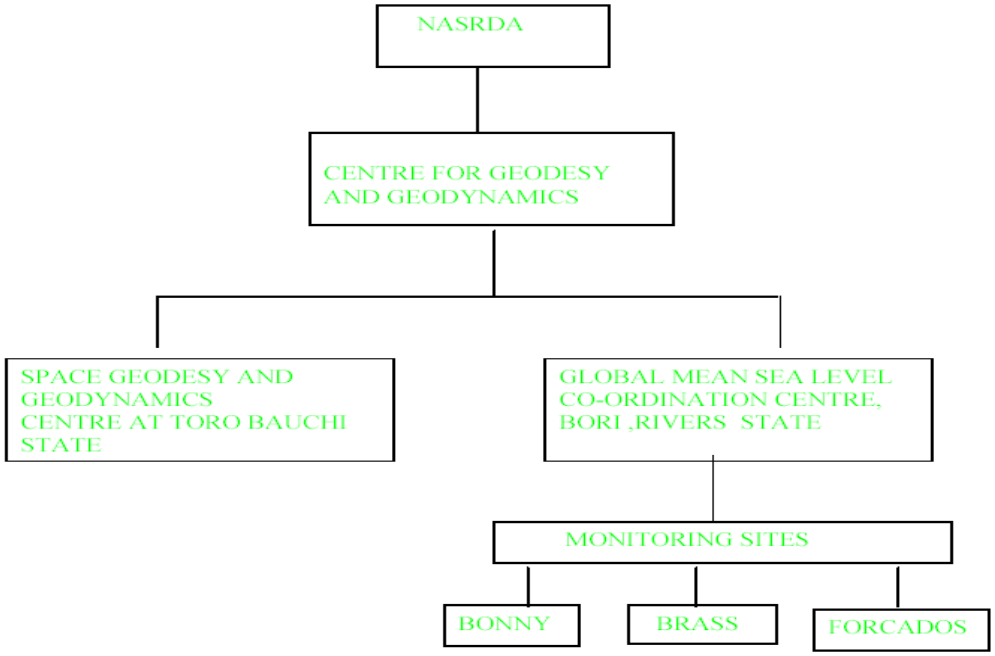
Appendix 2. Organogram for the Centre for Basic Space Science



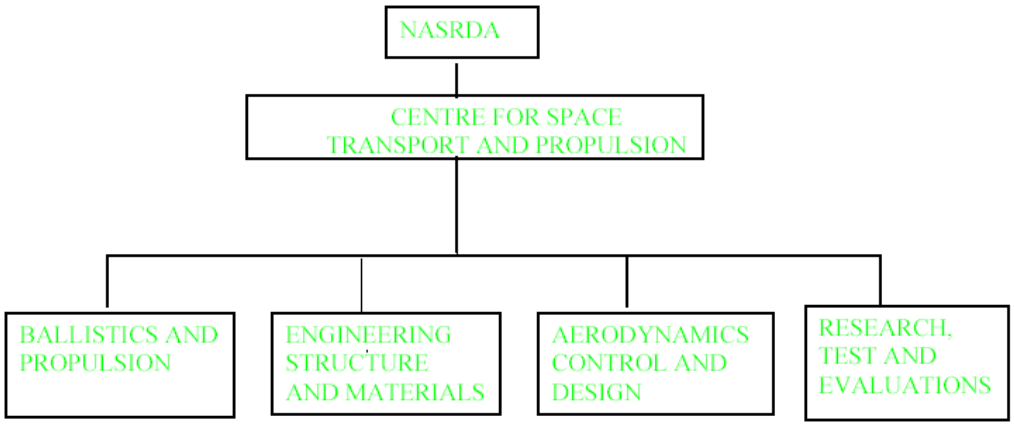
Appendix 3. Organogram for the Remote Sensing Centre



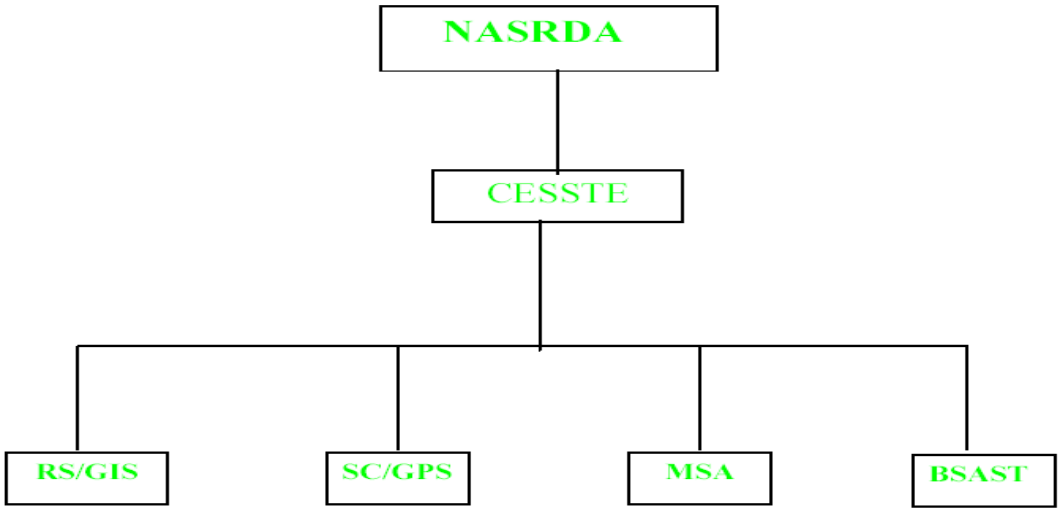
Appendix 4. Organogram for the Satellite Technology Development Centre



Appendix 5. Organogram for the Centre for Geodesy and Geodynamics



Appendix 6. Organogram for the Centre for Space Transport and Propulsion



RS/GIS – Remote Sensing and Geographical Information System.
SC/GPS – Satellite Communication and Global Positioning System.
MSA – Meteorological Satellite Application.
BSAST – Basic Space and Atmospheric Sciences Technology.

Appendix 7. Organogram for the Centre for Space Science and Technology Education

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