Third edition

Portable Architecture




Robert Kronenburg

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Third edition

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Preface to the First Edition

My earlier book in this field *(Houses in Motion: The Genesis, History and Development of the Portable Building,* London: Academy, 1995) was an attempt to identify the various diverse forms of transportable architecture and place them in context together for the first time. Whilst engaged in that research it became clear to me that within the history of architecture there was a prodigious variety of portable buildings and the first publication would need to be a foundation for further study rather than a detailed examination of specific types. The book was therefore designed as a historic survey which gathered together examples that expressed the philosophical and pragmatic issues which relate to portable buildings. In addition to that work, a detailed study and comparison of significant contemporary examples would be necessary in order to establish the crucial characteristics of portable architecture that have particular relevance today. In a built environment that is now affected more and more by rapid and dramatic change, ecological considerations, and social and cultural impact, a form of architecture that is flexible, lightweight in construction, has minimal impact on sensitive sites, and is responsive to new technological and aesthetic opportunities has great value. The intention of this study is therefore to place examples of good portable architectural design in context with each other, examine the common elements that have led to their creation, and thereby discover the factors that have been critical to their success. Analysis of these factors will be of interest to those involved in the design and manufacture of buildings (not necessarily all of which are portable) where similar issues are important. It may also result in further work that identifies valuable directions for future building projects and architectural research. The projects described here dispel preconceptions that mobile buildings are mainly low-cost, short-life products and confirm that the building type is an important part of mainstream architectural development.

All the teams involved in the design, manufacture and construction of the projects examined in this study have been generous in the time they have given, and the resources and information they have made available. Without their help it would not have been possible and I thank them all, especially Maurice Agis, Lorenzo Apicella, Mark Bryden, Mark Fisher, Nicholas Goldsmith, Kriss Kennedy, David Mellor and Paul Westbury. I would also like to thank the Building Centre Trust for their support during this research project, and Michael Gittoes, Chris Grech and Neil Warnock-Smith for their help and advice on content and publication.

Robert Kronenburg
University of Liverpool, 1995

Preface to the Second Edition

Most people, at least initially, think of the portable building as just a caravan or perhaps as the ubiquitous site cabin. The 1997 exhibitions, Portable Architecture (held at the Royal Institute of British Architects Architecture Centre, London) and Spontaneous Construction (held at the Building Centre, London) set out to dispel this misconception and the feedback I received as curator unanimously supported the view that they achieved this objective. The Portable Architecture exhibition was the most successful ever held at the RIBA Architecture Centre, with more visitors than any previous public event held at Portland Place. Unusual for an event held at the Institute, a large proportion of these visitors were not architects. The exhibition was widely reported in newspapers, the Sunday supplements, on radio and on television. Lifestyle sections carried features on inflatable furniture, temporary gardens, homes in trailers and barges. Architecture, at least for a time, once more became a part of pop culture – instant, available and fun. Comparisons were made with Archigram and the counter-culture ideas of the 1960s, however, this time it was different; instead of propositions the interest was aroused by real physical buildings and environments, erected by hard-headed businesses for commercial purposes. Simultaneously with the exhibition the first international conference on portable architecture was held at the RIBA, resulting in the publication of the proceedings in the following year. Though the effect of the summer's events were to some degree undoubtedly ephemeral (which is appropriate considering the nature of the exhibits), the readiness of the public to embrace the idea of portable architecture is significant and supports the notion that architecture can be movable and still be architecture.

In the first edition of this book I stressed my conviction that portable architecture is a part of all mainstream architecture. The circumstances surrounding the work of the two new designers featured in this edition provide conflicting indications about how much closer this idea has moved towards general acceptance. Powerhouse::UK by Branson Coates was the first major public building to be commissioned and completed by the new British government elected in May 1997. This would suggest that, at least in some official sense, the image of a provocative temporary building is not in conflict with the aspirations of quality and constance. However, the 'Airtecture' hall by Festo, a truly innovative building in many ways, has hardly been reported in the mainstream architectural press at all, though it has won many industrial design awards and been celebrated in dozens of specialist industrial and manufacturing journals. The purpose of this second edition of Portable Architecture is therefore the same as the first – to show that such buildings are eminently feasible, capable of a wide range of roles, and economic to build and operate. They can also be subversive as well as sensitive, amusing as well as appropriate, energetic as well as economic. All the case studies of the first edition remain, for the reasons they were originally included still hold true. Where design developments have continued I have added new information to these studies. New projects by previously profiled design teams have been included on the basis that they add something new in the way they have been designed, built or operated. I have not included projects built since the first edition which use strategies that I have previously examined; similarly, projects that have had their design, commissioning and construction explained in detail elsewhere are not covered here.

Once more I must thank those who have helped in providing resources and information on the new projects included in this edition, in particular Maurice Agis, Lorenzo Apicella, Doug Branson, Nigel Coates, Todd Dalland, Mark Fisher, Nicholas Goldsmith, Kriss Kennedy and Axel Thallemer. I would also like to thank Marie Milmore of the Architectural Press for bringing what was originally envisaged as a reprinting to fruition as a new expanded edition.

Robert Kronenburg
University of Liverpool, 1999

Preface to the Third Edition

This third edition of *Portable Architecture* is published at a time when interest in the potential of practical temporary and mobile buildings has never been greater. Many exciting new examples have been built around the world and many of these have received favourable and extensive media coverage. Journals and books in many languages have been published that explore the expanding ephemeral environment – furniture, events, landscapes, as well as buildings. The general media – magazines, newspapers and television – is also exposing a new wave of innovative design to an interested public.

Preparation of the second edition of this book was carried out whilst the experiences of the *Portable Architecture* exhibition held at the Royal Institute of British Architects Architecture Centre and the first international conference on this subject were fresh in my mind. As I write this, *Transportable Environments II* (R. Kronenburg, J. Lim and Wong Yunn Chi, eds, Spon Press, 2003), the proceedings from the second international conference on this subject has just gone to press, and the Vitra Design Museum's *Living in Motion* touring exhibition is on display at its second venue in Germany – attendance figures have broken all the museum's records and its catalogue is the fastest selling they have ever produced. Soon it will embark for Portugal, Spain, the UK and eventually the USA.

Despite this wealth of new and valuable information, *Portable Architecture* is still the only book that takes a case study approach to the examination of these buildings, exploring in detail the strategies and tactics employed by clients, designers, and builders to achieve the objective of creating a quality mobile environment. The number of design teams whose work is examined in detail is now sixteen and for this new edition they have been organised into three thematic sections: role models, problem solvers and specialists. The two new main case studies have been chosen not only for the particularly interesting approach taken to solve their design problem but also because they concern two of the most common building functions – the dwelling and the office. Eduard Böhtlingk's 'Markies' is an exemplar of economic, rational design that simultaneously has an immense capability to capture the imagination. It explores the heritage of trailer homes, caravans and tents, and transforms it into something new and vigorous. West McLaren Mercedes' Team Communications Centre is the most sophisticated, fast-deployment, mobile structure yet to emerge which still retains the imagery and reality of a real building. In addition to the case studies, the introduction has been revised and expanded to sample the growing range of projects by other contemporary designers working in the field of portable architecture and environments. These new mobile buildings are incredibly diverse in both function and solution. This work once again reinforces the fact that portable architecture can be utilised to fulfil all of the tasks that are usually demanded of static architecture and although, as with all design work, precedent is important, ingenuity and innovation are also crucial.

The purpose of this third edition of *Portable Architecture* remains unchanged – to show that mobile buildings are feasible, are able to fulfil many different roles, and are economically viable to build and operate. New projects have only been included if they add some new innovation in the way they have been designed, built or operated. In selecting them I have excluded work which uses strategies that are already examined in equal detail elsewhere. This book would not be possible without the cooperation and generosity of those who have commissioned, designed and built the buildings examined in the case studies. I must therefore express my real gratitude to those who have helped with the creation of this book by giving their time and material – in particular Maurice Agis, Eduard Böhtlingk, Simon Blackmore, Neil Burford, Todd Dalland, Mark Dytham, Mark Fisher, Giuseppe Lignano, Alan Parkinson, Jennifer Siegal, the TAG McLaren Group, and Axel Thallemer. I also thank Alison Yates of the Architectural Press for helping bring this new edition to fruition and the Leverhulme Trust for a study abroad fellowship that enabled important dedicated research to be carried out.

Robert Kronenburg
University of Liverpool, 2003

Illustration Acknowledgements

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Top left: Colourspace Maurice Agis © Pamela Brotons
Top right: Night view of the West McLaren Mercedes Team Communications Centre © *Racing Line*, TAG McLaren Group official magazine

Back cover
Top: Superbowl 2001 © Mark Fisher Studio
Bottom (four images): Markies Trailer © Eduard Böhtlingk

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Introduction

I

Portable buildings have been in use since humankind first began to build, yet because of their impermanent nature it is only recently that they have begun to be perceived as architecture.[1] Familiar traditional building forms such as the tent, tipi and yurt utilise sophisticated constructional techniques and complex habitation patterns that have not only retained their relevance for thousands of years but are linked to some of the most sophisticated building patterns of the present day. The Bedouin tent incorporates compressive struts and tensile membranes that utilise the same principles as modern tensile engineering systems. The North American tipi can be compared to a single cell of a space frame, adapted to use membranes without inherent strength (animal hides) and incorporating twin skin systems and natural air movement patterns for environmental modification. The Asian yurt uses modular manufacturing techniques and a geodesic-based wall structure that are familiar twentieth century constructional strategies. Contemporary portable buildings have a long and interesting pedigree, which includes principles that have been adapted into permanent construction.

Portable architecture consists of structures that are intended for easy erection on a site remote from their manufacture.[2] The simplest strategy consists of buildings that are transported in one piece for instant use once they arrive at their location. Some incorporate their transportation method into their permanent structure and may be built on a chassis or a hull. Such buildings are generally restricted in size due to the limitations of transport.[3] A more common strategy that also enables greater variety in built form is the building constructed from factory-made elements transported as a partly complete package and then quickly assembled at the site. The third type of portable building is composed of a system of modular parts that are easily transportable and usually dry assembled on site. This method allows maximum flexibility for adaptation to different layouts. However, it also usually requires a more complex assembly procedure carried out by a larger erection team over a

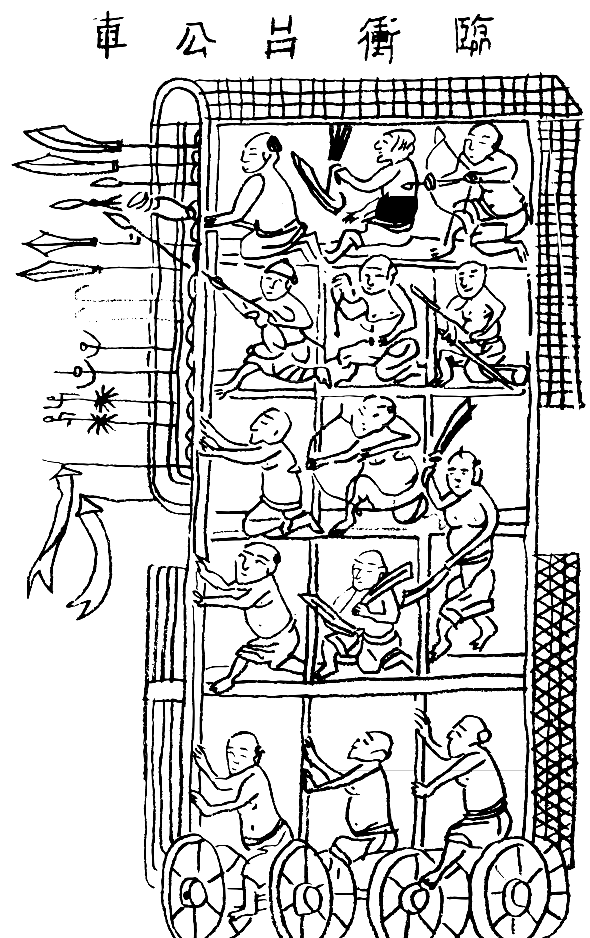

Figure I.1
A mobile Chinese assault tower (after a drawing in the Gujn fusho jincheng, an encyclopedia made at the order of the emperor Kangxi)

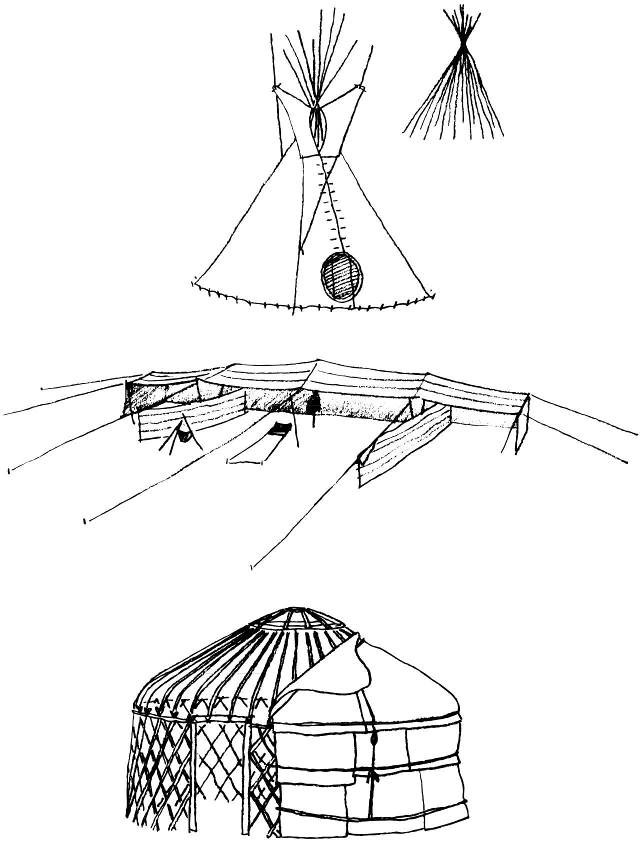

Figure I.2
Examples of traditional portable buildings, a North American tipi, a Bedouin nomadic tent and an Asian yurt.

longer period. These three basic strategies can be used with many alternative constructional systems that incorporate panel, framed, tensile and pneumatic structural principles, sometimes in combination, to create an infinite variety of built forms. The design of portable buildings is not restricted by the lack of construction options, which enables them to range in size and complexity from a Portaloo to a 10,000 seat auditorium.

The term 'portable architecture' may be used in recognition of the fact that many contemporary examples of these structures have a significant effect on the built environment. There is hardly a field of human activity that they do not support in some way – housing, education, medicine, commerce, manufacture, entertainment and military operations are a few.[4] However, a common perception of the contemporary portable building is that it is primarily a standard product such as the mobile home or site hut, and its presence within the building industry is peripheral – useful in the same way as a piece of machinery or a tool. The majority of small-scale applications are commercially manufactured, loose-fit products, which are acquired for their speed of deployment and are not dedicated to their purpose nor tuned to the activities they support. Though such standard products have their uses, they have very little in common with the ambitious projects described in this book. These use sophisticated construction technology to achieve impressive operational standards that fulfil diverse demanding functions. In these significant projects, the portability of the building has been a more important factor in the design selection than speed of deployment and sufficient lead-in time has been available for the creation of a dedicated solution. The mobile element in these projects' design has not only been the driving force in the creation of their form and image, but also an important factor in their operational success.

Precedent studies have an important part to play in the creation of a forward-looking enlightened architecture in that they provide a foundation of knowledge for current work, and allow successes and failures to be assessed with the benefit of hindsight. Perhaps most significantly they enable exploration of the complex relationship that exists between the overall intentions of a project and the means used in achieving them. The image, identity and aesthetic of any object may be identified as a series of abstract notions related to social conditions, culture and symbolism, however, its form is ultimately determined by the materials and manufacturing techniques used in its construction. Case studies are a valuable resource of first-hand experiences that quantify the physical attributes of a project by telling the story of its inception, design, manufacture, and operation. In this book there are twenty-nine case studies that describe projects by sixteen designer/constructor teams though many more are described in less detail in order to place the work in context. The projects have been selected for their diversity and the ingenuity and resourcefulness exhibited in their design – together they represent a cross-section of recent work in this area. Case studies that investigate failures no doubt also produce interesting information; however, I believe the task of this book is to open avenues of investigation rather than close them. The examination of these projects therefore concentrates on their positive qualities with particular reference to concepts, applications and strategies, which may not only benefit portable architecture but building design and manufacture in general.

Figure I.3
Caravans and trailers form an easily movable 'village'.

Each project was studied within a common framework of forty separate questions that investigated issues such as briefing, design, procurement, construction, deployment and operation, and future developments. To avoid repetition, not all issues are discussed in each case study and at the client's request, some information such as accurate costing, contractual arrangements, and design details that are the subject of patent applications, have been omitted for confidentiality. These case studies are not intended to describe every aspect of the project's design, manufacture and construction, but to concentrate on specific features that relate to the general issues of portable building provision. References are given at the end of each case study to enable easy access to more detailed information if required.[5]

Since the first edition of this book was published there has been a steady expansion in the number of built projects that are of sufficient interest to be included. As with the second edition, none of the previous case studies has been omitted, as the reasons for their inclusion are still pertinent. However, they have been edited and updated, and new projects added where they are of interest. The larger number of designers and construction teams which need to be effectively examined and compared in this edition has led to the book being reorganised into three thematic sections – role models, problem solvers, and specialists. This helps to order the examination of this expanding field into comparable areas based on the nature of the design teams and the characteristics of the projects

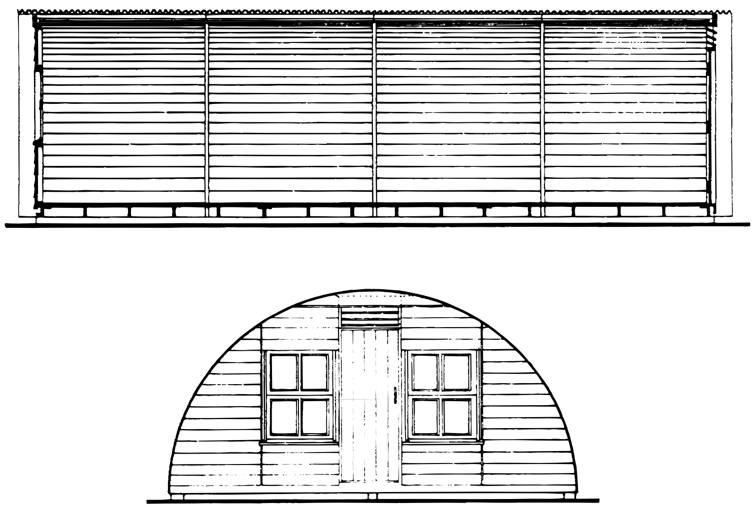

Figure I.4
The Nissen hut. The classic example of a simple modular demountable building. Built of corrugated iron, timber and glass, the standardised kit contained all components and a simple fifteen point set of instructions.

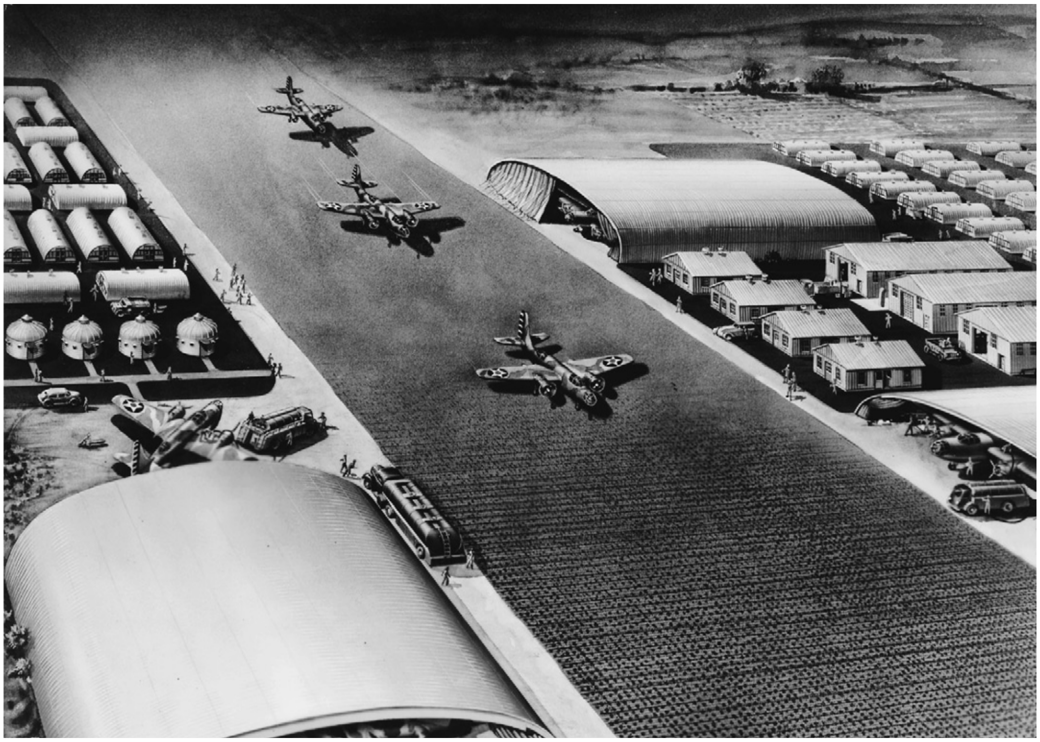

Figure I.5 The Butler Manufacturing Company, creator of the prefabricated Butler Bin grain store, produced a wide range of portable buildings for use by the US Military during the Second World War. This rendering shows a complete Butler airfield incorporating dwellings (including Buckminster Fuller's Dynamic Deployment Units (DDU), service facilities, hangars and the runway surface itself. The company is now a market leader in prefabricated building components used in both temporary and permanent situations. (Butler Manufacturing Company)

that are examined. However, it should be noted that although these divisions are convenient groups in which to examine and evaluate this very diverse work, they must not be viewed as distinct typologies or trends. Portable architecture is simultaneously a field of great variety and of inter-connections. In these projects, influences and experience can be identified not only with many different areas of architecture but also vehicle, product, and materials development.

Role Models

In every field of design a small number of specific examples stand out because they establish the integrity and value of the type. The four projects in this section have been chosen as representatives of particularly significant design approaches to the particular problems of mobile building because they each feature important philosophical concepts that exemplify the nature of portable architecture in general. It is not necessarily that they utilise materials and strategies which can be used directly in other portable building projects (though in some cases they do this as well) but rather that they indicate the special advantages which mobility can bring to an architectural solution. Their importance is therefore as precedents that indicate the opportunities, benefits, responsibilities and limitations of pursuing the portable route.

Renzo Piano Building Workshop's IBM pavilion is a sophisticated, highly serviced, complex building that has a unique character combining advanced technology with organic form. Its ambiguous beauty allows it to harmonise (rather than conflict) with a wide range of historic, urban, and arboreal settings. The pavilion designed by Future Systems for the Museum of the Moving Image is a simple structure of great beauty that accentuates its lightweight, ephemeral nature to create a distinctly different image from conventional architecture. It exemplifies technological innovation in the service of function rather than as applied image.

Tadao Ando's Karaza Theatre embodies traditional cultural concepts applied in a highly pragmatic logistical construction system that is ephemeral rather than mobile. Though the building's presence is transitory it nevertheless manages to maintain the continuity of historical architectural principles. Festo Corporate Design creates prototypical applications for the expertise in pneumatic and hydraulic control systems developed by its parent company. The Airtecture and Airquarium buildings are unique examples of the benefits of commissioning, designing, and manufacturing as an interactive experimental process.

The TAG McLaren's Team Communications Centre is a new case study for this edition. This remarkable project maintains the imagery and usability of a permanently sited commercial building, even though it is in reality a completely mobile, speedily deployable facility. It proves that the most demanding standards in terms of environmental control, state-of-the-art servicing and multifunctional operation can be met within an elegant architectural design.

Problem Solvers

The projects included in this section have been created by design teams who are actively involved in the development of pragmatic flexible buildings for use in a wide range of functions – many of which require conventional permanently sited buildings. The mobile solutions examined here have therefore emerged in response to the parameters of the specific project requirements. Although these teams have become experts in the design of portable architecture, this is not because they have selected that as their chosen field, but because the problem they wished to solve led them there.

Lorenzo Apicella's TSB and Hong Kong Tourist Association projects are relatively small-scale. However, the constructional systems they use are amongst the most innovative described here, merging conventional building systems, vehicle engineering and stage design to create completely portable kinetic facilities that still retain a definitive image as buildings. The Alec French Partnership's design for a mobile marketing centre uses familiar building procedures throughout to create a building that responds to the requirement for demountability, but which also possesses spin-off benefits in terms of speedy manufacture and erection. Nicholas Grimshaw and Partners' IGUS Factory is unique in these case studies in that the building has not been designed to be portable in its entirety. It has been included, not only because of the completely movable office and toilet pods that form part of its design, but also because of its unique flexibility in use which makes it a precedent for fully portable buildings as well as those with similar functions that are permanently sited. Buro Happold is one of the UK's leading architectural engineering design consultants and as well as the independent projects described here have been crucial collaborators on many important buildings including the UK Millennium Experience Dome. Their specialised portable designs regularly incorporate tensile membranes as an integral part of their construction, a developing technology that has undoubtedly been highly significant in the evolution of large-span buildings in recent years.

Though they are primarily known as architects, Branson Coates create projects which regularly cross the boundaries from building work into events and exhibitions. Powerhouse::UK is significant not only because of its use of largely conventional technology to create an especially memorable image but because it was a turn-key project in which the architects were required to retain control of every aspect of construction, erection and operation in order to deliver it on time and in budget. The second new case study for this edition is designed by architect Eduard Böhtlingk whose practice work on permanent buildings supported the development of his 'Markies' mobile dwelling over a ten-year inception to realisation period. The success of this highly visible, though small-scale project lies not only in the union between practicality and romance but its achievement in a high-quality product that operates reliably and with elegance.

Specialists

Though portable architecture should be understood as a part of all architecture, its realisation does not always derive from conventional circumstances. There is a wide diversity in the form and function of portable structures, which has resulted in a problem solving approach to design. In many cases specialist expertise has been developed both inside and outside the building industry during collaborative exploration between designers and manufacturers in order to resolve the issues of a specific project. This expertise has recognisable value in subsequent projects and therefore leads to the establishment of a specialist creative practice. This final section examines innovative projects by such design teams whose main work is outside the normal experience of general building practice.

FTL Design Engineering Studio are one of the USA's prime innovators in tensile membrane design, an expertise that has no doubt contributed to their position as a leading exponent in the design of large-scale transportable buildings. Though they have also designed permanent buildings for selected clients this work is habitually informed by their expertise in lightweight structures. Mark Fisher's primary role is designing enormous music tour sets that have a global media presence. These event structures utilise constructional methods and logistical arrangements not normally seen in the building industry, but which enable vast complex constructions to be assembled in hours and days rather than weeks and months.

FTL and Fisher are from an established architecture and architectural engineering background; however, a significant portion of the most exciting and dynamic mobile projects have been realised by others who would not regard architectural design as their primary focus (Festo and TAG McLaren would also fall in this category though each of these teams incorporates people who have architectural design experience). Maurice Agis is an artist who creates large complex coloured installation environments that rely on their portability to communicate directly with the public. Agis uses the materials and form of his pneumatic structures in an aesthetic sense to manipulate the senses of those who experience them.

The extra-terrestrial habitation projects by NASA architect Kriss Kennedy have yet to be built though they have reached the prototype testing stage. However, the practical transportation and erection problems considered in this work are similar to terrestrial projects, and because of the far more extreme conditions of their deployment are of special interest. Weatherhaven Resources Ltd. is an independent design/manufacturing/deployment organisation that has developed a unique holistic approach to the provision of shelter. They have created a logistical and constructional system that supplies buildings suitable for erection anywhere in the world, in any environmental condition, for any purpose.

Each of the design teams involved in these projects has generally worked quite independently of the other. However, there are some interesting common factors. One example is the way that engineering expertise in specialist lightweight building systems has been shared. Ove Arup engineer Peter Rice's input was valuable to both Renzo Piano and Future Systems, Neil Thomas worked with Lorenzo Apicella and Mark Fisher, and Whitby and Bird were consultants to Nicholas Grimshaw and Partners and the Alec French

Figure I.6
Mitsui Engineering and Shipbuilding Company, 'Polyconfidence' floating hotel for the North Sea oil fields, 1987.

Partnership. Though they are now separate organizations, Buro Happold and FTL were for some years engaged in a transatlantic partnership linked through their in-house engineering expertise.[6] Many of the design teams are also involved in more mainstream work for permanent structures and perceive their portable building design experience as an area of expertise which informs and is informed by architectural design in general. The functional operation of architectural spaces and facilities has clearly benefited from the expertise of those who are professional building designers. The design teams appear to have had little difficulty adjusting to the very different budgeting arrangements for portable buildings where the construction costs may only be a small part of a package that also includes transportation and operation, and constructional arrangements that may include builders and material and components manufacturers who do not usually work within the construction industry.

There can be no doubt that society is passing through a period of great change. Technological, economic and political shifts across the world are dramatically altering the way our built environment is shaped. There are many predictions of how the future will develop – few envision utopia, many foresee distopia. Most believe, however, that one thing will remain constant, and that is change! C.H. Waddington in his book, *The Man-Made Future*, summarises several research projects, which predict that change is in fact the only thing that can save the world from complete and dramatic network breakdown.[7] Many influential design professionals and commentators believe that flexibility and adaptability is an intrinsic component of a future-looking design agenda.[8] Contemporary architecture is already having to respond to significant influences that were deemed relatively unimportant until recently. Ecological considerations that measure the use of renewable resources, recyclable components and building costs based on a life-cycle basis are now significant as is the context of sensitive and historic sites and the restrictions placed on building design by planning controls and other legislation. Economic pressure on the building industry now results in fast track programmes for higher specification buildings built with less skilled personnel.

Portable architecture may be able to aid in the development of an industry-wide strategy that involves new materials, components and building methods. As a type of building design that must respond to relatively extreme operational parameters it more often makes use of experimental and exploratory logistical and constructional methods that may ultimately have more general value. Connections that exist between the portable building projects described in this book already indicate that there is a pattern of new phenomena that deserve further investigation. The expertise and experience of those normally not involved with the building industry is also of value in the development of new architectural solutions and it is in cross-over design areas like this that such benefits can first be appreciated.

II

In comparing these case studies three general themes emerge that are of particular significance – technology transfer, alternative logistical procedures, and human response to portable architecture.

Technology Transfer

The opportunities of technology developed in other industries are an important resource in design work that is concerned with solving new problems. The value of experience in both related and remote fields may be the identification of new applications that result either from the search for a solution to a particular problem, or by the recognition of an opportunity in a material or construction technique. One manifestation of technology transfer has been in the field of marine engineering. This industry is accustomed to manufacturing massive structures like oil rigs which must not only accommodate many of the functions of living and working but also support complex industrial operations in dramatic severe environments. Projects like *Polycastle* and *Polyconfidence,* designed and manufactured by the Mitsui Engineering and Shipbuilding Company, blur the boundary between construction and shipbuilding. These floating hotels were designed for off-duty oil rig workers in the North Sea and contain 600 and 800 bedrooms as well as cinemas, restaurants, and other leisure facilities.[9] At a smaller scale, but more directly influential on architectural design, the highly crafted aesthetic of yacht building technology has been adopted by architects and designers as yacht component manufacturers address themselves to this new market.[10]

Figure I.7 LOT-EK's Welcome-Box.

Also inspired by industrial products and the logistics is the work of New York design firm LOT-EK. Italian architects Giuseppe Lignano and Ada Toller have recognised not only the practicality but the beauty of the familiar facilities and machines that serve urban living: oil tankers, refrigerators, steel sinks, and shipping containers have all been used to make interiors and new buildings. LOT-EK creates a surprisingly bespoke architectural vision by making new architecture from old objects. Their work nevertheless conveys a contemporary image that has connotations with recycling and mobility.

Simply using a large object originally manufactured for another purpose means that mobility becomes an issue, if only to move it from the place in which it has been found to the place in which it is to be converted. However, mobility is also an intrinsic component in their overall design agenda – particularly in the projects that have involved shipping containers. The shipping container is a tough, modular, movable tool that is incorporated into a worldwide standard for ease of transportation. It is obvious that a building form based on this module can make use of the readily available cranes, lorries and ships for relocation purposes and it is common practice to convert shipping containers to make simple, temporary, secure storage facilities, site-huts, and rudimentary offices, etc.

LOT-EK's first realised shipping container project was the Welcome-Box for the Liverpool Biennial of Contemporary Art in 2002.[11] Sited to greet arriving visitors on the London platform at the city's railway station it presented a familiar object which had also clearly been morphed into something quite different to become both an art installation and a building with a practical use. Ramped entrances at each end led into a mirrored and black rubber padded interior in which video monitors projected changing images with an accompanying sound track. Manufactured in the

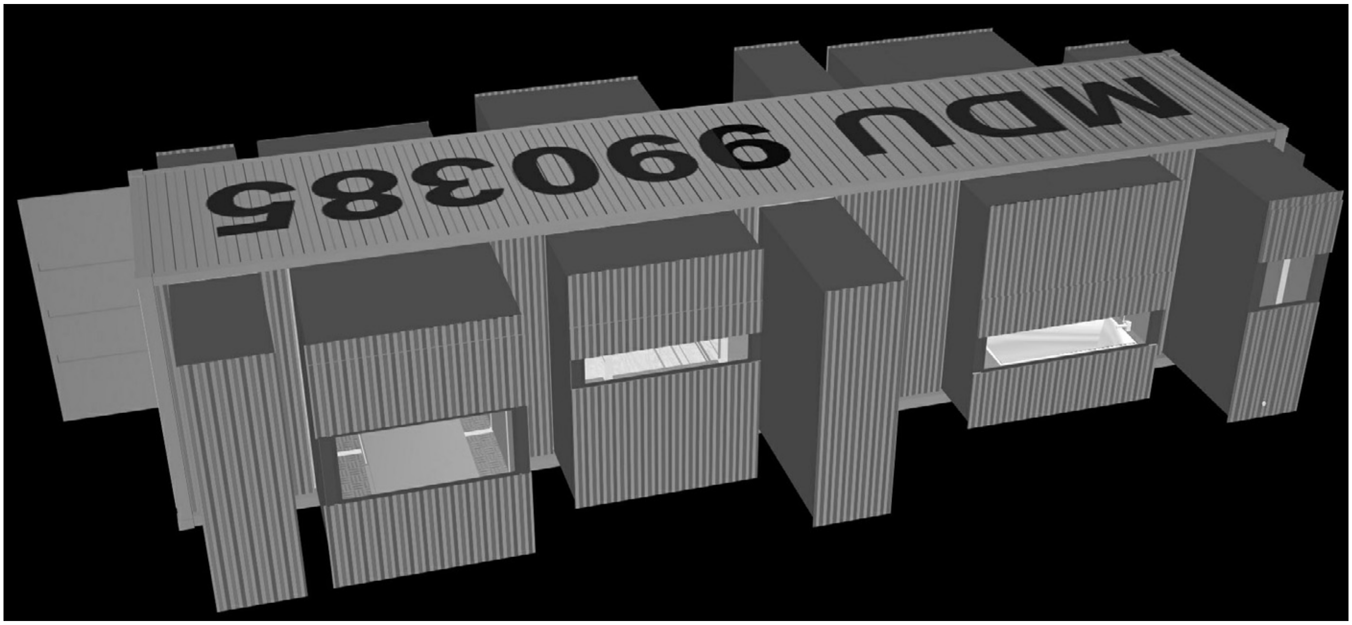

Figure I.8 LOT-EK's Mobile Dwelling Unit – the basic module is designed around the limitations of a standard shipping container.

Figure I.9 The MDU infrastructural frame.

Figure I.10 Klein-Dytham's Pika-Pika Pretzel hoarding in Tokyo.

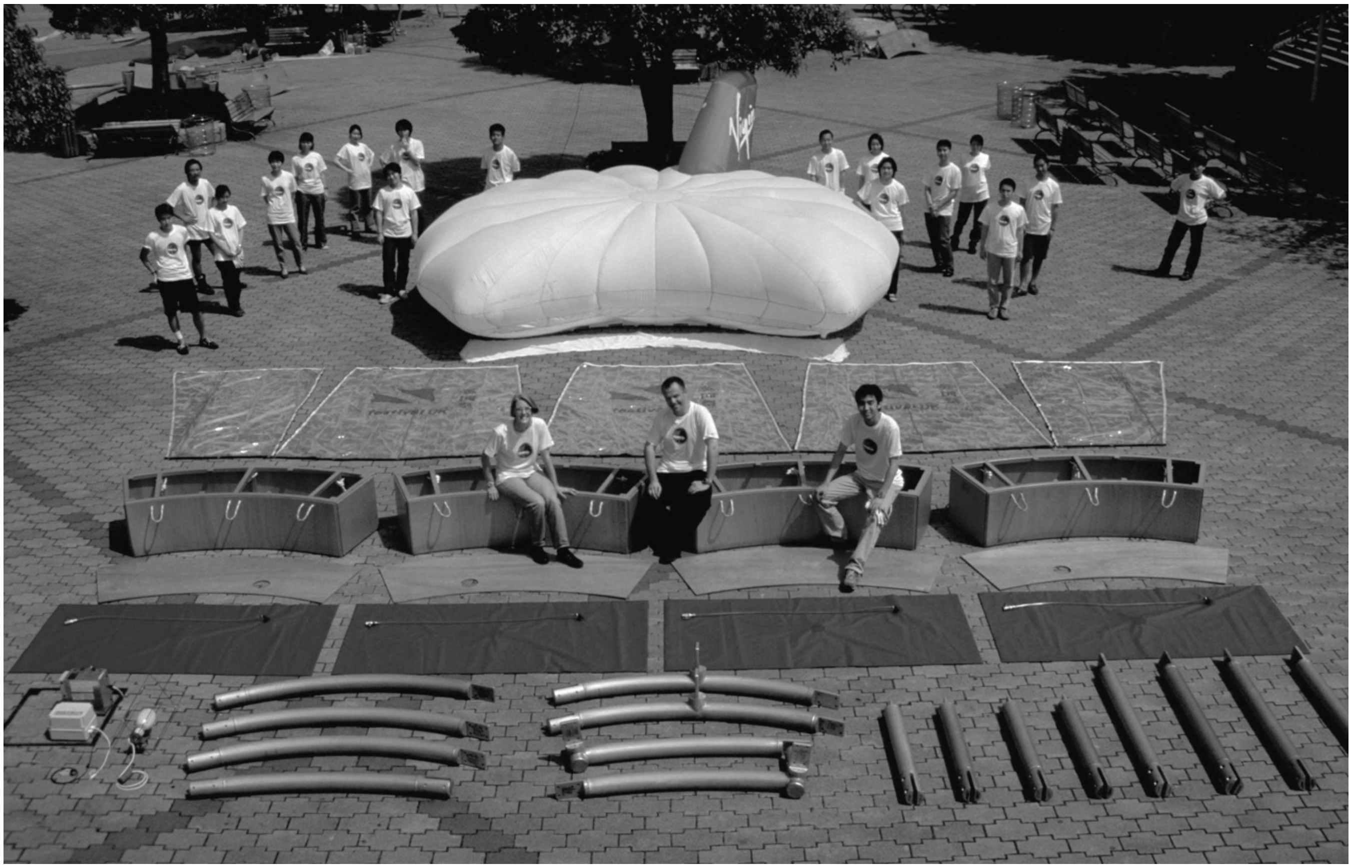

Figure I.11 The components of Klein-Dytham's portable pavilion for the UK'98 festival in Japan.

workshop and delivered to site and commissioned within twenty-four hours, the building was removed after three months and placed in storage to wait for the next event.

A much grander proposal is the Mobile Dwelling Unit (MDU) – a container-based home that is aimed at the growing number of people who prefer (or whose job requires them) to move around the world on a regular basis. The MDU is a shipping container that is a self-contained home, with push-out sections for sleeping, bathroom, kitchen and storage facilities. It is designed to be located at any of the world's ports – transported on container ships, and slotted into a specially made infrastructural frame at its destination. The MDU allows the traveller to have a home in every port, a real dedicated and personal dwelling with the continuity of their own possessions, though with a changing view from the window. Though the idea of a flexible, infrastructure-based, ever-changing city environment is by no means new (Buckminster Fuller and Archigram proposed it – Kisho Kurokawa and Richard Rogers tried to build it) this idea makes use of readily available, well-tested logistical systems, that genuinely support the relocation of dwellings on a continuous basis rather than the appearance of plug-in architecture without the reality.[12]

The possibilities of adapting materials and construction techniques from other industries such as aerospace and car manufacture has been advocated by many commentators since the beginning of the twentieth century and though many exciting prototypes exist, the full impact of widespread technology transfer has yet to be exploited. Portable architecture uses a much greater range of innovative materials and constructional techniques than conventional building projects and it is therefore at the forefront in the exploitation of technology transfer opportunities in the building industry.

Mark Dytham and Astrid Klein are two UK-educated architects who established their practice in Tokyo in 1991. Their work frequently crosses the boundaries between building, product and media design and their use of new materials and building methods, in particular plastics and inflatables, has given the practice a reputation for innovation and

Figure I.12 UK'98 pavilion.

eye-catching imagery. In a country where urban land values are so high that the building can become a relatively small part of the total development investment, transient fit-outs are common. However, as well as such temporary installations, Klein-Dytham have built some genuinely portable projects. Their use of a polyurethane-coated nylon membrane (the same material used to make high altitude balloons) to create a temporary site hoarding for International developer VELOQX's first project in Japan created a memorable image to announce the company's arrival but also to draw attention to the high-profile commercial location in Harajuku, Tokyo. The 34-metre long site boundary was framed in metallic panels with brightly coloured circular descriptions of the new building's purpose surmounted by an intricate pneumatic wall rising to 12 metres above pavement level. The project was called Pika Pika (Japanese for shiny) Pretzel (named for the shape of the inflatables). Metalised polyester was laminated to the nylon to make it shiny whilst the holes were left translucent so that the structure would also work well at night with internal illumination.

Another hoarding project was for the multi-conglomerate British company Virgin – an interactive wall that asked questions of passers-by who could text their answers to win prizes. Virgin were sponsors of Klein-Dytham's most significant portable building so far – a mobile pavilion for UK '98, a year-long festival of cultural events in Japan promoting British products and services. This structure consisted of five separate pavilions that could be erected in a number of different arrangements both in terms of layout and form, though the dominant recognisable image of an inflatable polyurethane-coated nylon cloud remained constant. This shelter was supported on four aluminium stilts located into base supports that could also serve as seating. The frames could also be fitted with side panels if needed for privacy or protection from the weather. The building was transported to more than thirty different venues throughout the year.

Logistics

Construction and operation strategies often have to be very different for portable building constructions. A particularly difficult logistical problem solved by Mark Fisher was how to create a complete stage with amplification and lighting rigs that spanned across the entire 45-metre width of a football field in 4.5 minutes during the 2001 Superbowl half-time interval. Fisher created a completely demountable system that could be erected solely with human power utilising 450 willing volunteers. As the players left the field the vast team ran on carrying the structure's components and proceeded to erect the 18-metre high structure in front of the 78,000 audience. The ensuing show was seen on live television by an estimated 115 million people.

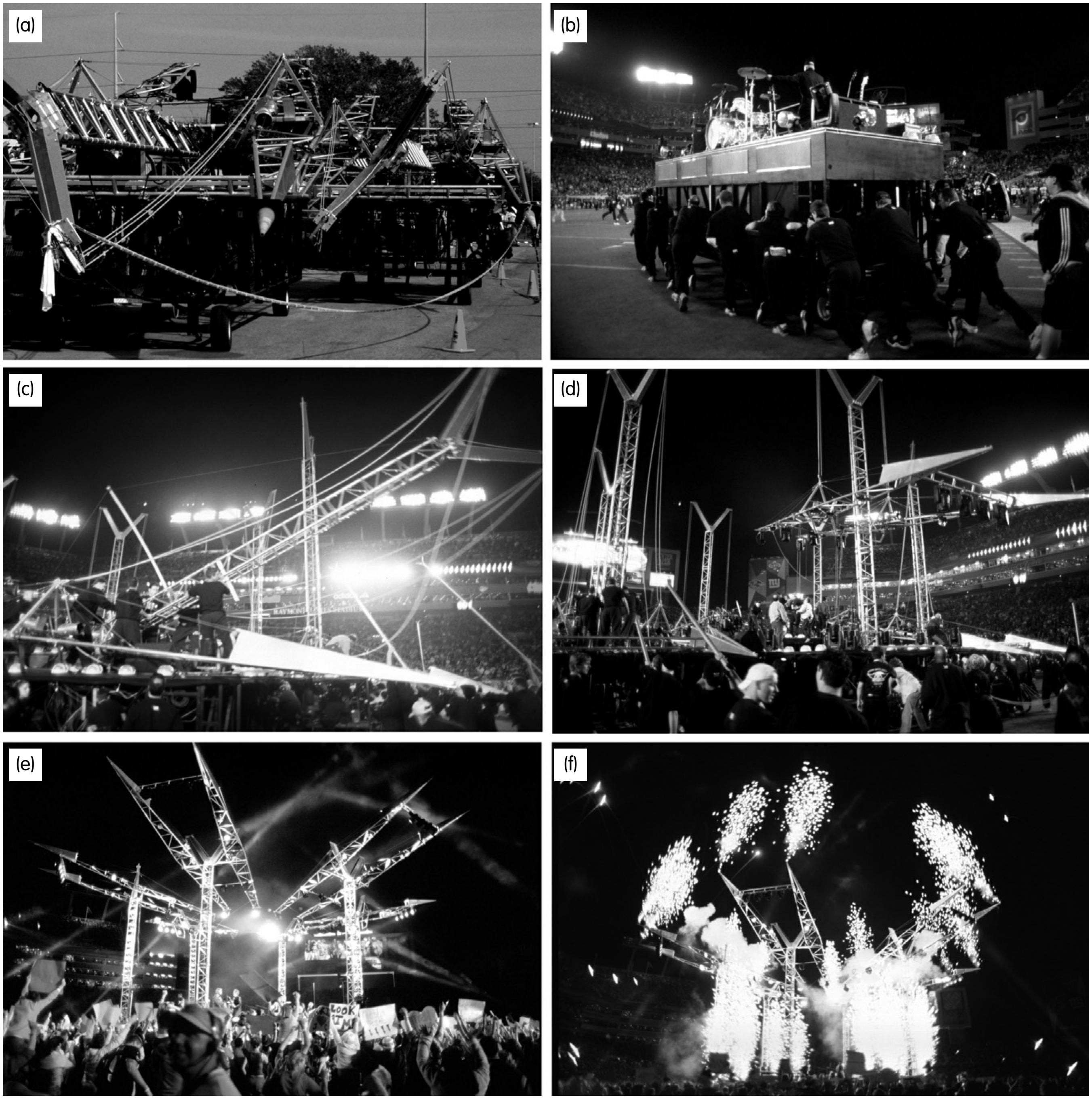

Figure I.13 Mark Fisher's stage for the Superbowl 2001 half-time show; (a) the stage is prepared on rolling dollies; (b) the dollies are pushed into the arena for assembly; (c) the masts are winched into position; (d) the lighting and pyrotechnics catamaran are winched to the top of the masts; (e) and (f) the show begins and ends.

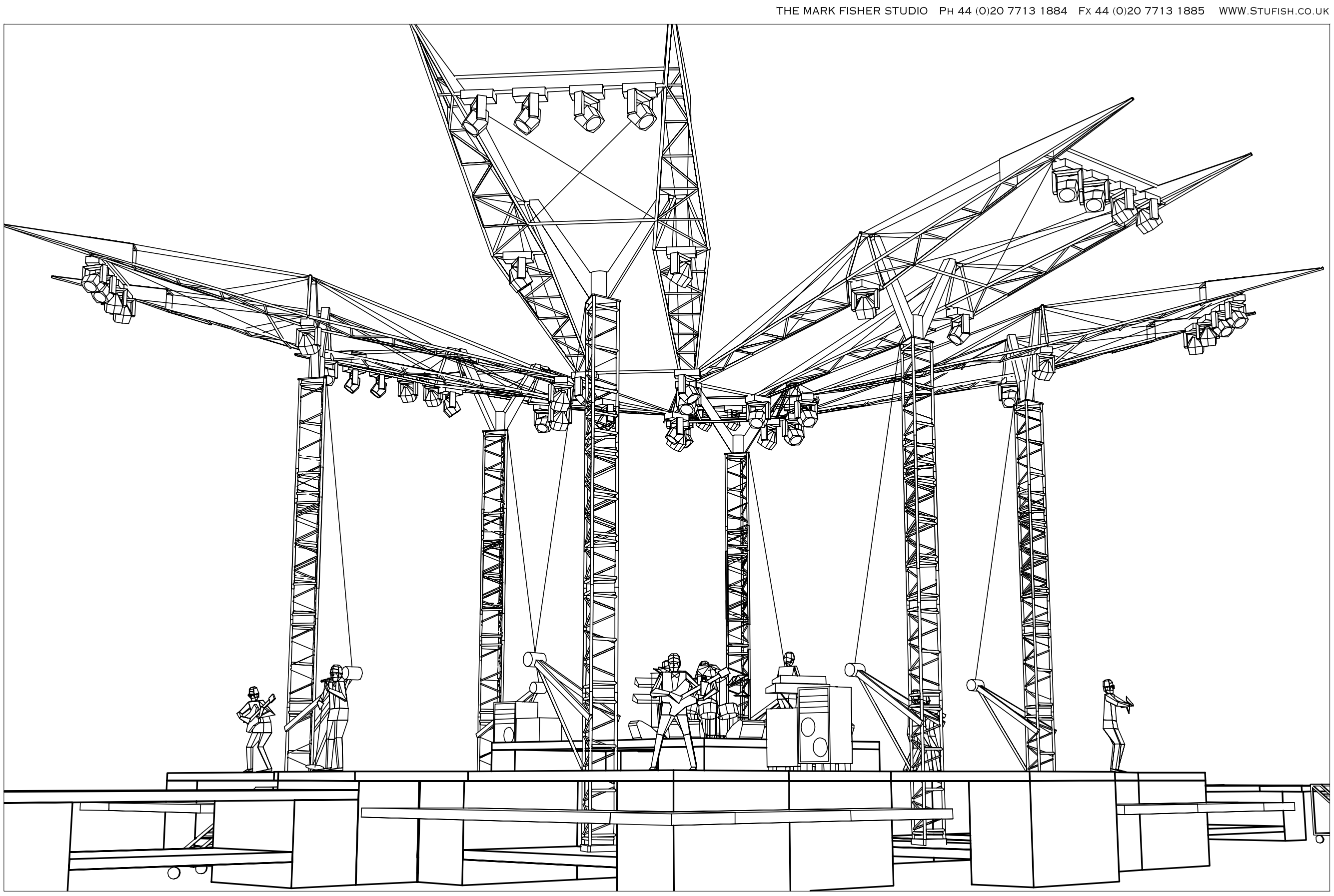

Figure I.14 Superbowl 2001 half-time show general arrangement drawing.

Though not usually as extreme as this, most portable structures demand easy assembly and disassembly and this results in the selection of construction strategies that utilise prefabricated, modular, dry jointed systems with repetitive components. Performance requirements also affect the choice of materials for components, which need to be lightweight and compact for easy and economic transportation. Speed and cost of erection are important factors, which depend on the skill level and size of the erection team and have resulted in the development of automatic erection systems such as those designed by Lorenzo Apicella and TAG McLaren. Portable architecture design affords more opportunities for experimentation because buildings that are created for temporary sites, specific tasks and a defined lifespan are generally not associated with long-term, low risk investment. The logistical problems associated with mobility mean that specific solutions are sought to specific problems rather than by the adoption of readily available standard systems. The portable building also represents the potential for a truly recyclable construction system in which whole buildings can be moved to different places for different uses, or broken down into their component parts.

Portable architecture uses some of the most innovative forms of building yet devised which makes it a valuable testing ground for the rest of the industry. One example is manufactured building which utilises factory production techniques to provide high quality buildings at low cost. The mobile home industry provides a quarter of all new houses in North America with factory-made buildings which are transported either as completed dwellings or as double-wides, and which are joined together on site. The competition winning house designed by Abacus Architects in 1994 utilised existing mobile home construction techniques to develop a high quality low cost prototype home. The house was built on a production line in three weeks, delivered to site for assembly and was ready for occupation two and a half weeks later.[13] There

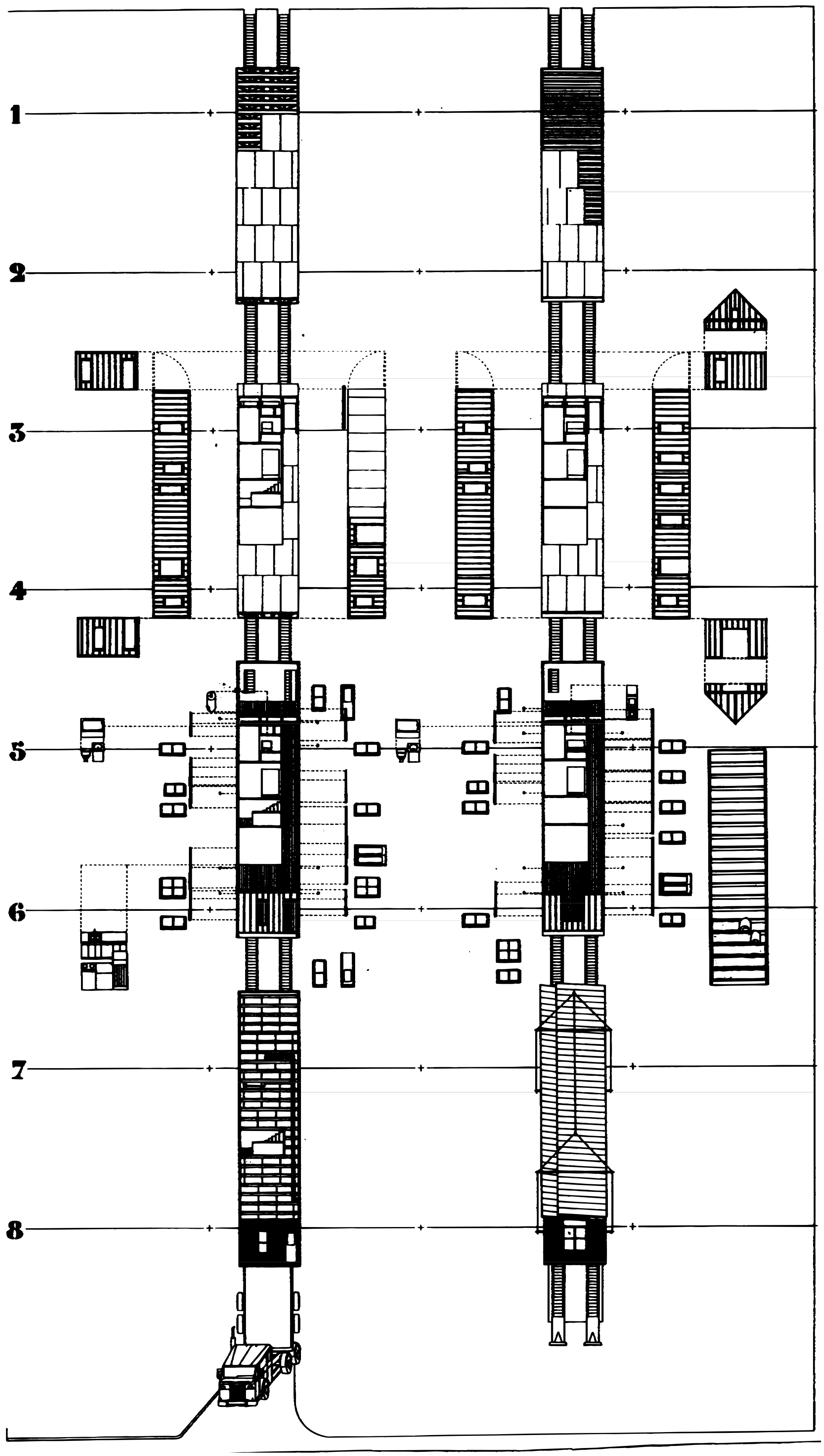

Figure I.15
The 'Progressive Architecture' house designed by Abacus architects, Boston, 1992. This competition winning design was built by mobile home manufacturer Stratton Homes on their production line, then delivered to site in two separate volumetric units.

has also been considerable recent interest in the UK regarding the potential of prefabricated techniques to solve the parallel problems of too few homes being available at too high a cost. For example, architects Cartwright Pickard, in collaboration with clients The Peabody Trust, and manufacturers Yorkon (a part of the Portakabin group), are one of several groups involved in designing high quality housing based on the strategy of factory-built modules that are then transported to site in order to reduce construction time significantly.[14] There are many functional and operational factors common to both dedicated projects such as the Acorn House and standard systems like Yorkon's and experience gained in one area may be used to improve the other.

Human Response

Perhaps the most important (yet most difficult to evaluate) common feature of these case studies is the reactions that people have to portable architecture. Practical benefits are relatively easy to understand once they are quantified; however, the way in which people respond to the temporary characteristics of structures they are accustomed to thinking of as permanent is complex. Portable buildings can do almost anything that permanent ones can – and they are also frequently capable of fulfilling other functions that would be impossible by any other means. Portable buildings have a low environmental impact; they may be located in rural or urban situations with minimal long-term effects. They can make use of a temporary identifiable address that is of value to both the operator and the visitor, in that high profile locations can be used to increase the numbers of people reached in a given time period. Unusual building forms that are temporarily sited in familiar settings can also change people's view of their environment and maybe give them the impetus to more clearly recognise its positive and negative attributes.

The work of artists that crosses the boundaries between installation and architecture has an important role to play in bringing a new and different appreciation of familiar places and environments. The work of Maurice Agis is studied in detail in this book. However, there are many other artists who are influential in the field of experimental mobile environments: Joep van Lieshout is a Dutch environmental and performance artist who has created a wide range of provocative work from his studio outside Rotterdam which deals with the ability of personally manufactured objects to support our desire for personal freedom. In particular, his group of collaborators and assistants have manufactured a series of 'mobile homes' that are simultaneously sensuous, romantic, amusing and, at least to a certain degree, practical proposals for transportable, towable and clip-on living and sleeping spaces. Projects like the La Bais-ô-Drôme are made using a range of simple materials and techniques, wooden frame, glass-fibre – Atelier van Lieshout have even published a construction manual to help others invent and manufacture their own alternative caravan.

American artist Andrea Zittel has also used the building of a personal mobile home as a way to examine critically the conventional homes that most of us have no choice but to live in. Her A-Z Homestead Units are miniature trailer buildings with all the comforts of home; seats, beds, toilets,

Figure I.16 Sprite Musketeer mobile art gallery on location in North Wales.

Figure I.17 Sprite Musketeer interior.

and a personal collection of the artist's objects. Their desirability and completeness in containing all the services and comforts we require seem to question the need for anything more. Her A-Z Personal Compartment Units are more like a demountable modular living space, with different function areas linked together through circular openings. It also stimulates comparisons with a conventional home with its evocative character that is part playground, part play-house, part hamster's cage.

The Sprite Musketeer does not deal with the question of home though it is based in what was once a mobile version of one, but the way in which we relate to places, in particular the landscape. It is a standard touring caravan commercially built in the 1970s which has been converted by artist Simon Blackmore into a mobile contemporary art space. The project was originally funded by the Arts Council of Wales as a mobile viewing station that reinvented the tradition of landscape painting. The structure was stripped of its interior except for a simple bench that faced the rear window. Painted orange to contrast with the external natural environment the caravan was placed at critical positions alongside the road in such a way that the audience could sit inside and admire a framed view of the landscape that alluded to those painted in previous generations by great artists such as J.M.W. Turner. Sound and video recordings were made to capture the views, ambient noise and the conversations of those who took part in the experience. A subsequent project explored views in the Lake District. However, the Sprite Musketeer has now become a mobile venue in its own right, where small numbers of people can have intimate viewings of video works.[15]

Like Maurice Agis, Alan Parkinson sculpts space, light and colour with inflatable poly-vinyl chloride (PVC) structures. Since 1990, Parkinson's team at Architects of Air has been building and exhibiting 'luminaria', mobile sculptures that people can enter to experience undiluted luminous colour. The various structures: Eggopolis, Meggopolis, Ixilum, Levity, Luminarium V and Arcazaar, are made from unsupported PVC which has no reinforcing fabric so that the colours may be seen at their purest. The PVC, made by French manufacturer Ferrari, has good strength, is flexible in a range of temperatures, and comparatively resistant to fire. PVC does, however, deteriorate with air pollution, the effect of ultra-violet light, and temperature extremes so each of the luminaria have a projected life of 200 exhibition days.

The starting point in the design is the footprint of the installation layout, the aim being to provide the most interesting and exciting experience for the visitor – the creation of surprise and discovery are key elements. Limitations are the structural stability of the volumes and the desire to keep the outer perimeter of the installation to the smallest possible area so that the range of potential host sites is kept to the maximum. The installations are capable of being dismantled into a convenient number of portable parts so that they are easy to transport. They must also be stable in use so they are designed to drain quickly of water, and are tied down with frequent anchor points in case of strong winds. Up to 120 anchors can be used for one installation, either sandbags or concrete blocks on hard surfaces or 800 mm long bar pins on grass. The luminarias are designed to be fully accessible to all so floor areas and entry and exit points are kept flat to the supporting ground surface (usually grass) to allow the passage of wheelchairs. The shapes of the volumes are limited to cones, spheres and cylinders

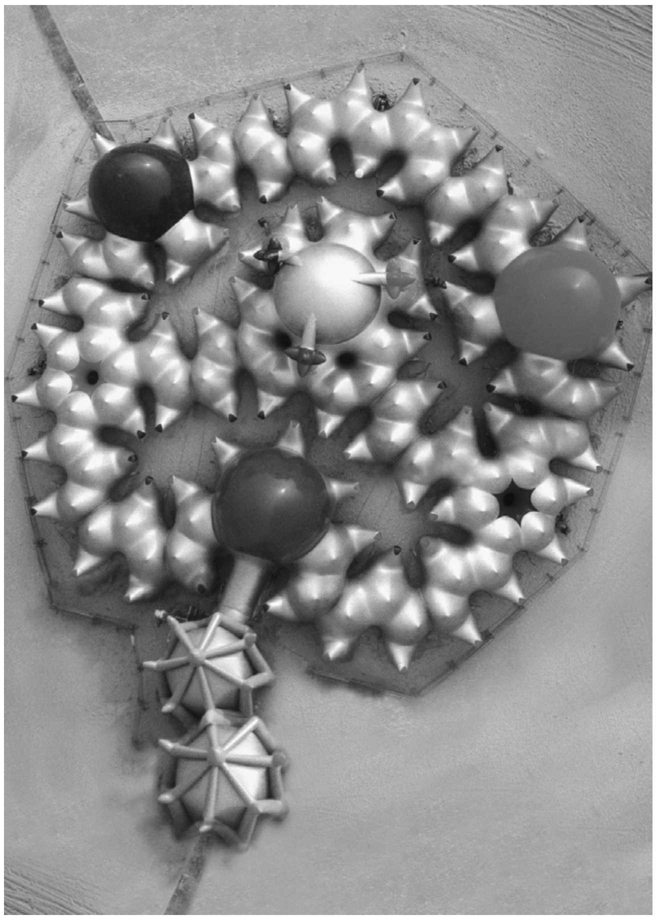

Figure I.18 Architects of Air luminaria 'Arcazaar'.

Figure I.19 Architects of Air luminaria 'Levity' sited at Somerset House, London.

Figure I.20 Interior of a luminaria in Manchester with an external statue visible through structure's skin.

because of the pneumatic pressures on the unsupported PVC; however, the combinations and size of the shapes can have great variety.

Once a design has been established the PVC can be cut to shape using hardboard templates and glued together along its seams with Bostik 3206 adhesive. Though fabrication is straightforward a single structure will take six people about five months to complete. Installation on a grass surface takes from four to six hours, but on a hard surface it takes longer (eight hours or more) because the anchor points take longer to position. Nine blowers are used to inflate the structure which generate twice as much air pressure than is required to keep it erect, thereby providing an ample factor of safety in case a rupture occurs in the membrane.

The latest Architects of Air project is Arcazaar based on 72 three-sided domes inspired by modular repetitious structures seen by Parkinson on a recent visit to Iran. One benefit of this new form is that a much longer visitor journey with greater variety can be contained within the same sized ground plan. Arcazaar therefore has intricate weaving pathways which open out to vistas, intimate small spaces, larger, more dramatic ones, and apparently independent pneumatic columns formed where six domes meet. Architects of Air structures are part art installation, part entertainment, part revitalization of the public space and have been experienced by over a million visitors in twenty-five countries on five continents. Like Agis's work they not only create a unique experience for the internal visitor, they also open up a world of surprise for those who live and work near the site of the installation, seeing an instant building size structure of extravagant form created in a once-familiar space over night. Parkinson states that visitors are frequently casual passers-by, drawn in by the enticing vision of a large structure that flexes as people lean against its walls and shivers and vibrates in response to the movements of those who are already inside.

Portable architecture has the potential to communicate a shared experience to geographically dispersed groups of people. This was one of the objectives of the Swiss centennial pavilion designed by Mario Botta in 1991. This building was made from thirteen ingeniously hinged trussed beams (representing the thirteen cantons that founded Switzerland) that supported a crown of twenty-six poles (representing the twenty-six current cantons) and it travelled to regional centres throughout the country to reinforce the common history of a people who speak several different languages and have a variety of geographic backgrounds. The building occupied important historic settings during its tour, linking together the historic matrix of the nation with a modern structure redolent with potent new symbols.[16]

III

Portable architecture should not be seen as some unique hybrid manifestation, part way between transport and building design. It is without doubt a facet of mainstream architectural design. This can be justified with a number of reasons, some pragmatic and others more philosophical. All good portable architecture sets out to create an identifiable sense of place in exactly the same way as a permanent building does. The fact that its physical existence on a particular site may be subject to dramatic erection and dismantling procedures and be comparatively limited in time, also adds a sense of excitement associated with event and performance. This phenomenon may be compared with the accelerated motion of a speeded-up film that provides a fascinating view that compresses a process that normally takes much longer. No matter how long the building is present on a particular site, for that period the portable building's primary function remains the same as a similar permanent facility – to provide shelter and foster the activities that are accommodated. The way in which it achieves this should not be compromised by its portability and the user should not have to suffer inferior standards simply because the building happens to be movable. Many standard products stress their instant availability as a key factor in their marketing and expect clients to compromise their performance standards for this benefit. The good designer approaches the task of creating permanent or portable architecture with the same set of priorities, balancing all the factors pertinent to the project. Portability is just another factor like lighting, security or access arrangements. Designer or client may decide that the portable element in the design brief may provide the opportunity for the creation of a specific image associated with movement, but it may equally be one of

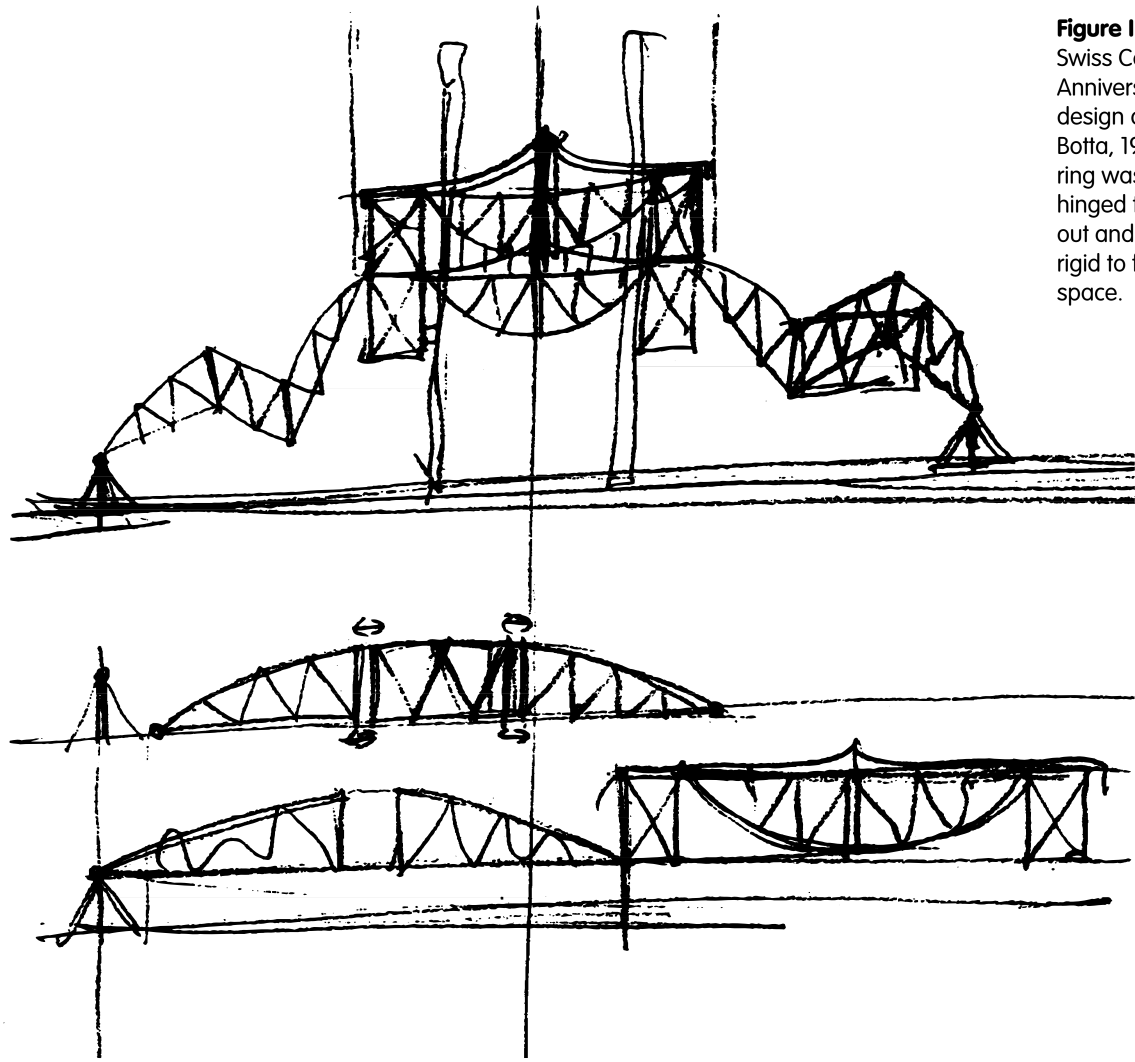

Figure I.21
Swiss Confederation 700th Anniversary mobile pavilion, design drawings by Mario Botta, 1989. As the central ring was raised in the air the hinged trusses straightened out and were then clamped rigid to form a column-free space.

stability and continuity that is required. All portable buildings should therefore be judged by the same criteria as other architecture – fitness for purpose, appropriate for context, beautiful in form, economy in use.

Due to the particular circumstances of their erection, portable buildings are generally composed of relatively lightweight materials. This is a characteristic that can be traced from vernacular and traditional examples through to the latest computer-aided designs that are made in factories. In general, materials are expressed in their construction because to disguise them is to add unnecessary complexity and additional weight. This also applies to their structural composition, which enables a clear identification of the difference between supporting elements and cladding elements. Well-designed portable buildings exhibit clarity of architectural expression which makes them exemplars of functional form generation, and they therefore occupy a place at the forefront of architectural design development.[17] This reinforces the reason why portable architecture is part of the mainstream – the methods of construction and techniques of manufacture it pioneers are applicable to all types of buildings. The use of lightweight prefabricated componentised construction can reduce site work, building time and transportation costs. New building methods originally devised for demountable buildings have been transferred to permanent constructional operations – components developed for a primary market in permanent buildings are now being used in portable structures. It is therefore clear that the study of the design, manufacture, construction and operation of this particular architectural field has potential benefits in all.

However, there is a lack of coordinated research activity into portable building techniques. Industry-led research is primarily legislation-led and concentrates on increasing the standards in existing products to meet more stringent statutory requirements. The introduction of user-led research could lead to the development of new markets and applications. Innovative one-off designs like most of those described here are a valuable research resource in that practical examples of working structures can be used as models for future investigation. Projects designed to challenge existing construction methods such as Festo's 'Airtecture' hall are very rare. Created as a purely experimental building incorporating wholly innovative constructional and operational systems, its purpose is to explore the envelope of architectural design, to reinforce the technologically advanced image of the company who made it, and to prototype unprecedented research and development ideas. Though clearly a piece of architecture, it stands outside the normal world of the building industry due to its unique commissioning, design, construction and operational characteristics.

In some cases the expertise of professional designers is already being utilised by parts of the manufacturing industry (marquee tent manufacturers employ Buro Happold in the UK and FTL Design Engineering Studio in the USA) and this is an optimistic sign for future development. The objectives of a coordinated industry-based research programme would be to improve the image of the portable building, to communicate its advantages and develop its potential. This will not be easy – the difficulties of transferring research into application is reinforced by many projects which have been successful in prototype but failed to make it into large-scale production.[18] However, the examples described in this book convincingly indicate the potential of portable architecture – a potential to be both the best architecture and the best engineering.

The nature of this book is that the case studies are primarily projects that have been taken to completion. However, it is of interest that several of the designers included here are currently involved in much more ambitious projects. Lorenzo Apicella, now a partner with the international design firm Pentagram, and engineer Neil Thomas of Atelier One are currently working on The Communicator, a mobile building of more than 3000 square metres that can travel to corporate events throughout Europe. The clients, WCT Communications, operate and manage a wide range of corporate and commercial presentation, education and conference events and need a highly flexible portable environment with a powerful, identifiable image. The structure incorporates a central steel mast and a radial network of aluminium portal frames that support an insulated PVC roof membrane. It has an aluminium floor system, ramps and stairways, and a perimeter wall of interlinked GRP panels. The internal walls will also be movable to create different, flexible environments depending on the demands placed on the facility by its users.

FTL Design Engineering Studio are also involved in the creation of a new communication venue. The 'Machine Tent' for the Harley-Davidson Travelling Tour (celebrating the motorcycle manufacturer's 100th anniversary) is the only custom-designed component in a large travelling show that will be

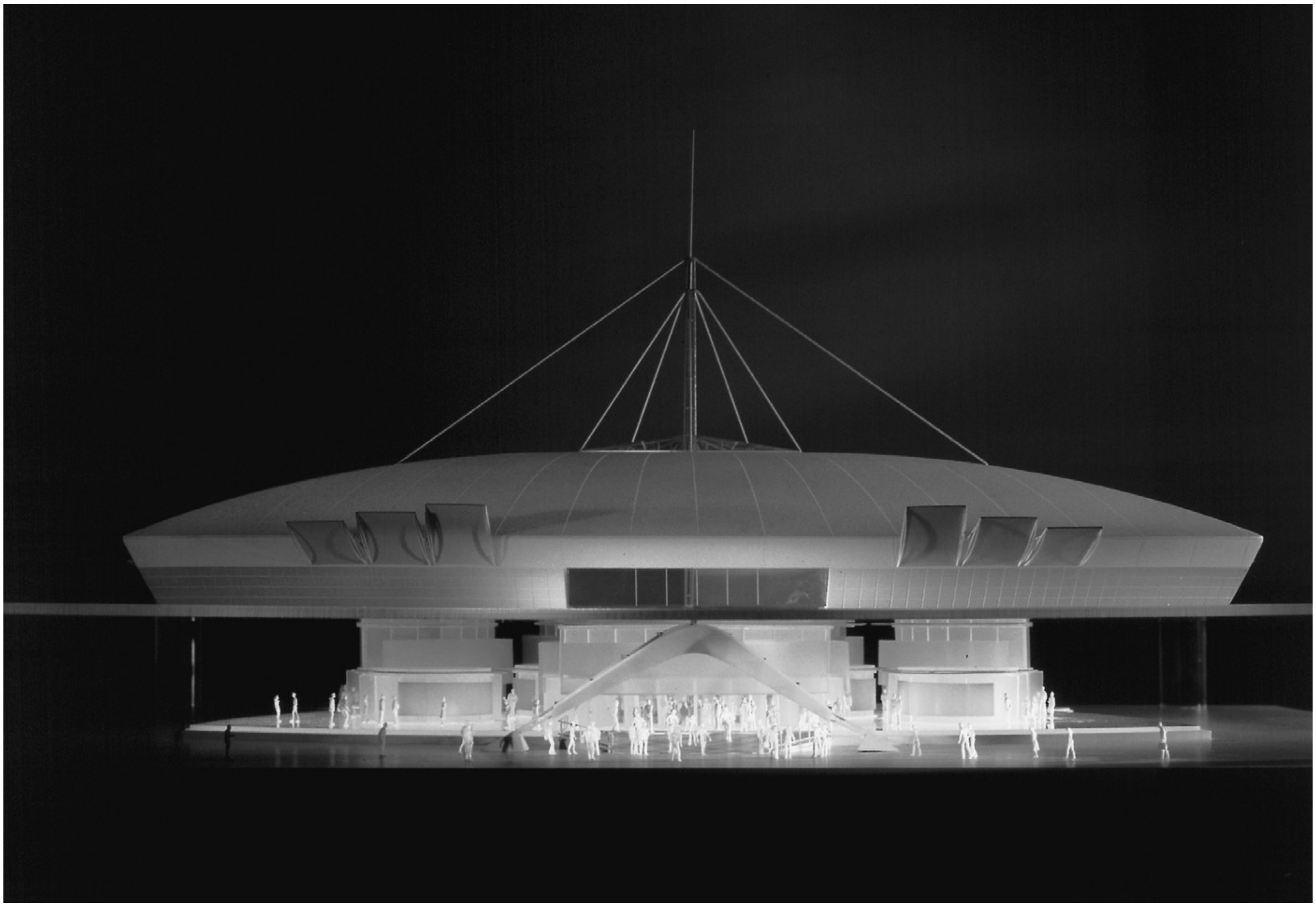

Figure I.22 The Communicator, Apicella Associates and Atelier One – a portable events and presentation facility.

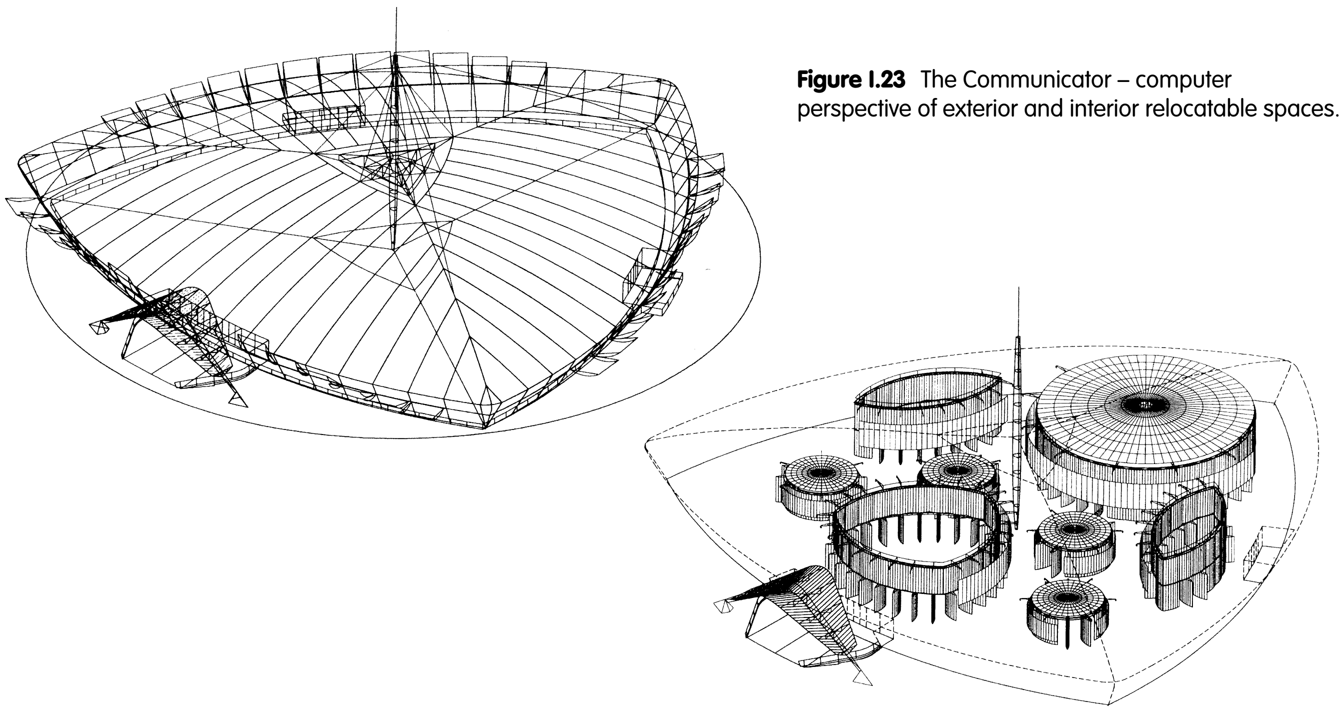

Figure I.23 The Communicator – computer perspective of exterior and interior relocatable spaces.

Figure I.24 FTL Design Engineering Studio's 'Machine Tent' for Harley Davidson's Travelling Tour, 2002.

Figure I.25 FTL Design Engineering Studio's 'Machine Tent' for Harley Davidson's Travelling Tour, 2002.

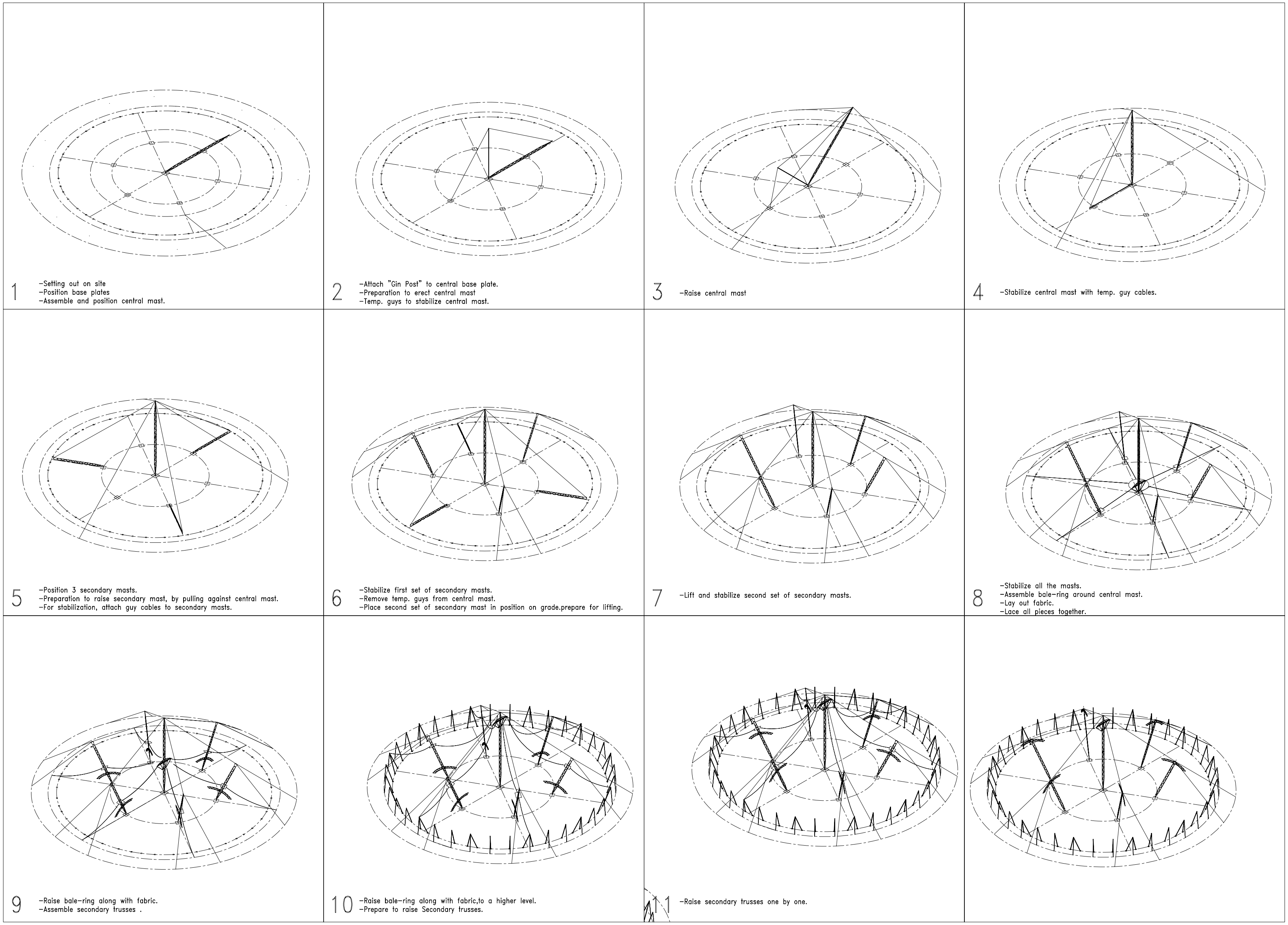

Figure I.26 The 'Machine Tent' erection process

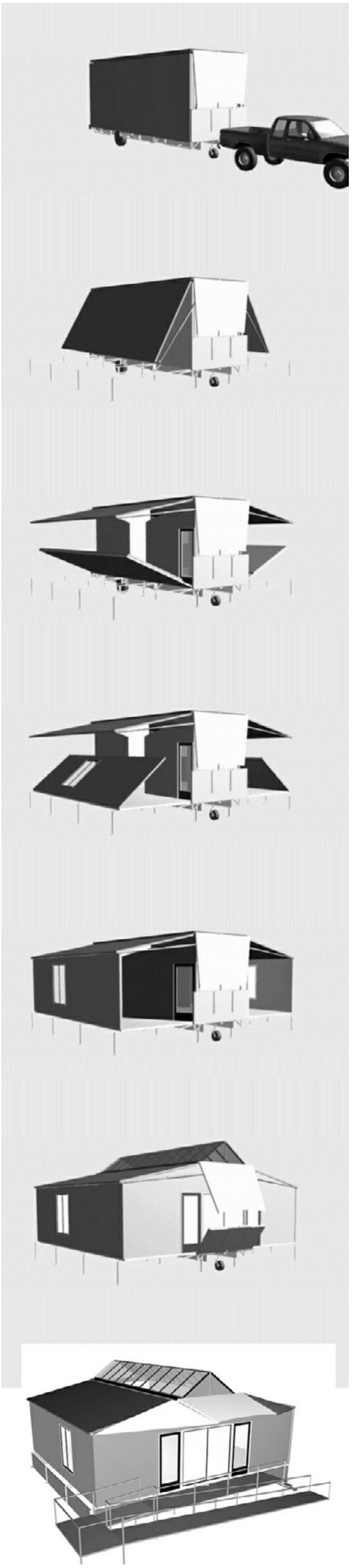

Figure I.27 NY City Mobile Classroom project – deployment sequence.

set up not only in the US but in Tokyo, Sydney, Cologne, Mexico City, Vancouver and Barcelona. The challenge was not only to make a structure that would accommodate the varying building codes and erection conditions in these different parts of the world, but also to meet the deadline which required all design, engineering and construction be completed in under twenty weeks. The solution was to create a 50-metre diameter building that could be erected in just three days without the use of heavy cranes or other equipment. The building consists of a central mast and six secondary masts that all have internally mounted winches, which haul up all the required elevated components. The curving segment that caps the secondary masts creates an internal element reminiscent of the motorcycle structures exhibited previously (see Figures I.24 and I.25), but also provides the building's unique external form. The elements that compose the six fields of the circular design are all identical to allow for quick and easy assembly. Although using the latest technology the building sits firmly within the tradition of the circus tent – reinvigorating it with contemporary meaning.

FTL partner Todd Dalland is also developing an innovative new facility for the New York Public Schools Authority. This is the first completely transportable mobile school campus, designed not only to accommodate surges in school populations as students move through the system from elementary to high school, but also to allow the entire student and teaching body to be relocated whilst refurbishment takes place. Existing mobile classrooms are similar to 'double-wide' mobile homes in form and are relatively difficult to move as they need to be lifted into place by crane and connected to permanent services infrastructure. The environment they provide has also been widely criticised. In collaboration with architects Marty Raab, Prakath Nair and Richard Dattner Partners, FTL have developed designs for a range of buildings that can be deployed from a dedicated staging area at relatively short notice, easily transported on public roads to be in use within twenty-four hours. They comprise classrooms, administration, a library, specialist rooms for art, music, science, information technology, a cafeteria and a gymnasium and incorporate self-contained power generation, air-conditioning, fresh and waste-water storage within the individual units providing flexibility of deployment and layout and the ability to be used independently if required. The prototype is to be built on a 1.5 metre long trailer and uses fold out walls to make a 50 square metre classroom. The objective is to make an environment that is conducive to teaching, capable of quick and easy deployment, and costs less than the inadequate structures currently in use. The connotation that these buildings have with beneficial change is also important to the client in that they embody a recognisable sign of improvements being made in the city's educational provision.[19]

FTL's workload is not restricted to terrestrial projects – they are currently collaborating with Honeywell in developing a mobile airlock for use with the next generation of smaller and lighter space vehicles that will replace the thirty-year-old Space Shuttle design in less than ten years time. As both volume and mass are at a premium when lifting cargo into space, everything that can be done to eliminate irregularly used facilities saves on fuel and increases potential payload. Design work has been done using software (Rhino, FEMAP, and NE/NASTRAN) that is frequently used to create the tensile membrane buildings that form a large part of FTL's workload.

FTL and Honeywell have designed and prototyped a deployable space room that can act as an air-lock when astronauts need to exit the vehicle. The structure is stored beneath the aerosurface of the vehicle during launch and re-entry and is deployed when required with the use of pressurised air beams and air muscles, gear-driven telescoping struts, and pressurisation of the interior space. The outer fabric is six layers thick and provides protection from micrometeorites and the massive temperature differential of space, the inner six-layer fabric contains the air pressure that rigidises the structure. A full-scale low fidelity mock-up has been completed and small scale tests that accurately represent the performance extremes are under way.

The diverse nature of these projects' functions and the innovative forms employed in their logistical and constructional solutions may lead to the perception of movable building projects as unconnected discrete phenomena. However, though their diversity means they could never be grouped together into a style or movement, these designs respond to similar crucial current issues and an examination of the case studies in this book does show some interesting correlations between projects which indicates that though certainly not a 'movement' perhaps there is a *zeitgeist* emerging in which they share. These correlations can be found spread across the entire range of building design, procurement, construction and operation and reflect changes that are occurring not only in the building industry but also throughout the entire commercial world.

Figure I.28 Spacewalk entry module for NASA's next generation space vehicle.

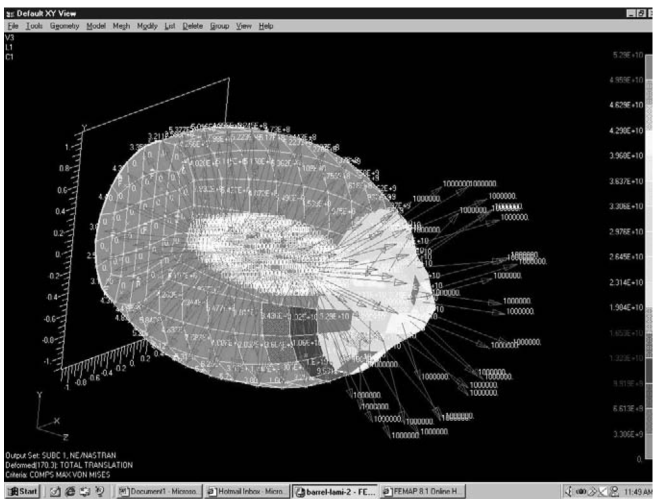

Figure I.29 Spacewalk CAD drawing.

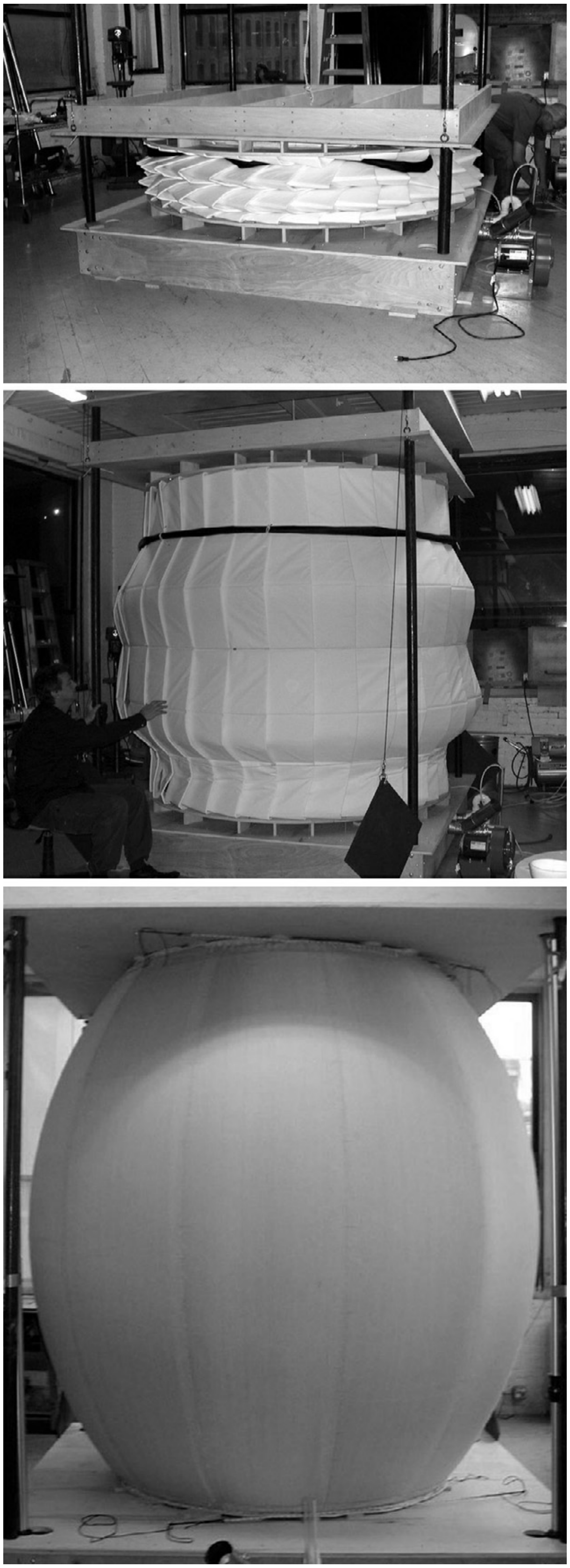

Figure I.30 Spacewalk prototype deployment testing.

Most of the buildings described here have been commissioned by clients who are unsure what they actually want, though they have a clear idea of what they want to do – instead of saying they want a 'building', they may say they want an 'exhibition', or an 'experience', or a 'shelter'. The designer has therefore been placed in a much more powerful role than usual – as well as advising on architectural form and construction he or she may also be determining operational criteria and siting.

The nature of commissioning is also different, utilising much less formal contracts based on performance related goals rather than strict provisions of space, volume, and environment. Rather than a desire to get the most space for the least cost there is an understanding that the achievement of the facility's goals within an acceptable budget is the prime objective. In addition, operational costs are often taken as a part of the budget – energy, transportation, maintenance, erection and dismantling costs emerging as equally important elements in a predetermined cost package. It is also of interest that though contracts are far less involved, the actual projects are frequently far more complex and incorporate many more variables than in conventional building. In the case studies described here, the performance criteria stipulated in the contract have usually been exceeded – the building costing less to operate than originally forecast, capable of speedier erection, and having a longer life or secondary use beyond the parameters of the initial brief.[20] The clients received more for their money thanks to the ingenuity of the designer and the skills of the contractor.

Portable architecture is as varied in form and image as mainstream buildings. However, some common factors can be perceived and these relate primarily to materiality. Though its image does not fall into a set visual pattern, there is one factor that is common to most designs – these buildings appear to represent something new. This may be explained by the understandable recourse of designers to light and strong materials which are best suited to the requirements of transportation and demountability and the lightest, strongest construction methods consist of comparatively high technology systems.

Even when the designer's ambition has been specifically to create a portable building that has the presence of high-quality architecture (rather than high-quality temporary building) the image created is still one of lightweight, modern efficiency. Membranes are becoming increasingly common in either tensioned form or as air-supported structures. This is not only because

Figure I.31 MOD deployable shelter by J.T. Inglis and the Lightweight Structures Unit at the University of Dundee.

increased performance and longer life can be expected from the new range of membranes but also because of the relative ease with which they can now be manipulated at the design stage due to computer aided design. Architects can create three-dimensional forms in physical or computer generated models, which can then be transferred to programmes which carry out the detailed stress calculations and pattern making. Advances continue to be made not only in the creation of new products like ETFE foils and elastomers, but also in the development of well-proven materials like canvas. Perhaps the traditional image of the tent membrane as the classic portable shelter has helped reinforce its new role in making architecture. Indeed, though the introduction of new materials is significant, it is also true that the full potential of traditional materials such as canvas have yet to be realised. The Lightweight Structures Unit (LSU) at the University of Dundee has designed and built several prototypical mobile structures that use the latest modelling techniques to push back the boundaries of what was previously thought possible with this material.[21] Working with textile proofer J.T. Inglis, the multi-disciplinary team from the Departments of Architecture and Civil Engineering have tackled a Ministry of Defence brief for a rapid deployment tactical shelter. The resulting building is 9 metres long by 6 metres wide by 3 metres high and weighs just 90 kilograms. Its elliptical form provides strength, rigidity, and the maximum usable floor space. The truss uses a tightly woven, balanced weave polyester sail cloth web and glass fibre reinforced polyester resin ribs with an ingenious hinge system that allows the truss to be collapsed and deployed easily. The entire building can be packed into a cylinder 3.2 metres long and 300 mm diameter and is light enough to be carried by four people. Only two people are required to erect the building, which takes less than ten minutes.

Figure I.32 The MOD deployable truss utilising a web of polyester sail cloth.

Figure I.33 LSU and Arena Seating's mobile canopy system.

Another project by LSU is a mobile canopy system designed in collaboration with Arena Seating, the UK's leading supplier of outdoor event seating. The canopy is an elegant cantilevered arch that springs from the back of a standard mobile stadium seating section. The arch is made from two aluminium ribs that create a ladder-like structure with stainless steel top and diagonal cables. The frame and the membrane are assembled together at ground level and then a winch, located at the base of the truss, bends it into its rigid working shape. This radical departure from traditional methods provides many important advantages in terms of safety and speed and convenience of erection.

As these two projects are aimed at volume production, much of the design work has not only been in creating and proving the concept but also in maximising component integration to simplify factory production and thereby reduce manufacturing costs. This is an important factor in contemporary mobile building design where conventional solutions already exist – the new approach will only be adopted if it can fulfil its task more efficiently, more economically with at least the same level of reliability.

Plastics such as glass reinforced polyester, fibreglass, epoxies and polycarbonates are being used in a wide range of other roles besides membranes, for poltrusions, jointing, tension lines, webbing, windows, doors, and rigid panels. Aluminium and steel remain the most common compression member materials for their availability and familiarity in component manufacture. Where costs allow or performance dictates, new advanced technology materials such as carbon fibre and Kevlar are being introduced. These spin-offs from other advanced industries inevitably surface first in building designs that have high performance requirements combined with the necessity to retain low weight.

Advances in control systems are also now affecting portable building designs making possible self-levelling mechanisms, hydraulically and pneumatically operated components, self-deploying structures, and self-monitoring and responsive envelopes and environments. These systems, once restricted to static, permanently located machinery, have now become sufficiently robust, compact, and economic in the use of energy to be portable.

Despite these inevitable technological advances, many of which find their first use in the creation of portable architecture, such buildings do not exist just because the new technology is now available to make them. Buildings that move from place to place have been designed, made and used for millennia. The need for portable buildings is what drives the demand for them – the fact that they can now be made more easily or more efficiently simply makes them more attractive as an alternative to making wasteful disposable buildings in the same situation. It has been suggested that the building industry does not need any more new materials or techniques at all, what it really needs to do is build better with the old ones.[22] Traditional portable buildings have frequently used commonplace materials such as timber, rope, cloth or felt to create sophisticated, environmentally aware, finely tuned buildings. Most contemporary designers have a natural inclination to explore the potential of the latest, lightest, most modern products in order to achieve their goals. Frequently when the budget does not allow these materials to be included they

Figure I.34 OMD's Eco-Lab, a mobile building made from recycled components and materials.

have been forced to use more prosaic methods – plywood, standard steel sections, rope, canvas, etc. Sometimes they perceive this as a failure or a compromised solution; however, the cheapest, most commonplace materials, free materials, or those which have been repeatedly recycled, can also make wonderful spaces and forms – for example, polythene sheet containing water for foundations, unprocessed wood for walls, and air under pressure for a roof. Where the building use is temporary, the siting of limited duration, and the impact transient, experimentation is as valuable for an innovative low-tech building as it is for a high-tech one.

One designer who has built several mobile buildings from recycled materials is Jennifer Siegal, whose Office for Mobile Design (OMD) is based in Los Angeles, California. The majority of OMD'S built work has involved community and education agencies and she is an advocate of the do-it-yourself, self-help approach to creating buildings. Though OMD's range of speculative work is wide, from mobile shops and information technology centres to houses Siegal's most significant built projects have been community based mobile educational facilities constructed on donated truck chassis' with recycled 'free' materials. The Eco-Lab is a mobile classroom that contains a multi-media programme explaining the importance of environment and sustainability to the local community. Made from cast-off film sets from the Hollywood film industry, the structure has a definite building-like quality, with natural materials – a wooden floor, a woven slat wall – being predominant. The unique ability of mobiles to provide an event upon

Figure I.35 Eco-Lab model.

arrival as they transform from vehicle to building is utilised to engage the children's interest. From a closed-in lorry shell it becomes a permeable, light-filled space, with layers of plants cantilevering from the sides. The children are encouraged to follow a route through the various zones of the structure learning about the 'life of a tree'. Along the way, each student receives a sapling, which they are asked to water and take care of, finally meeting in a discussion space for questions.

The Portable Construction Training Center (PCTC) was designed for a non-profit organisation that wished to develop affordable housing for low-income and disadvantaged people.[23] The aim of the facility is to provide a classroom that can be used to teach their apprentices building construction

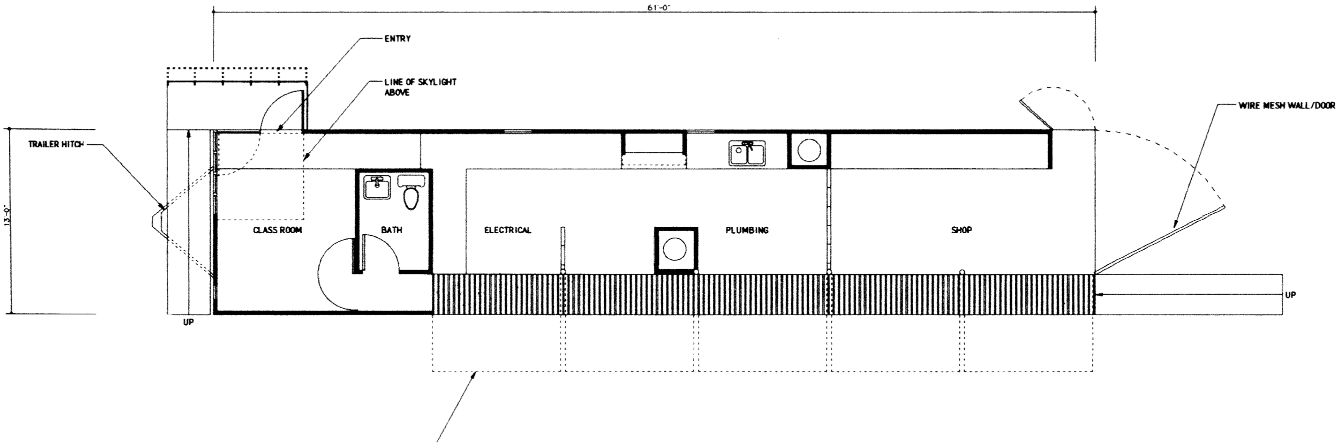

Figure I.36 The Portable Construction Training Center (PCTC) plan.

Figure I.37 PCTC open and ready for use.

skills such as plumbing, painting, carpentry, plastering and electrical installation. One side of the large 20-metre long trailer folds open to create a porch which accesses the different zones dedicated to each of the skill. Tool kits disengage from the facility for use in the surrounding space and a 3.8 metre square meeting and group-teaching space is provided at the entry point. Entirely built from pre-used and donated materials by design and build students from Woodbury University, the image of the building is a practical, yet energetic and engaging response to its purpose. The concept of a building that not only can be taken to where a rebuilding project is underway, but then also opens up for free access and use, is one that combines the joint ambitions of reconstruction and education.

IV

The field of portable building design is challenging and varied and because of this the design experience it engenders can also have value in the development of new strategies for static building projects. Perhaps the most high profile building to be erected in the UK during the twentieth century has been the Millennium Experience Dome, which owes its form, construction, use of materials and structural systems to portable building precedents.[24] The main design partners involved with the Millennium Experience projects were the London based multi-disciplinary design group Imagination Ltd., architects Richard Rogers Partnership, and consulting engineers Buro Happold. The concept for this building emerged in the summer of 1996 when Ian Liddell of Buro Happold, Gary Withers of Imagination and Mike Davies of Richard Rogers Partnership put together a proposal for a building that would cover all the exhibition components within a single giant envelope allowing them to be made without the constructional constraints of external weather conditions. This enabled the project to meet both the budget and the extremely tight programme timetable. Over the next few weeks, Buro Happold developed the engineering concept for a fabric-clad, stressed cable dome supported by twelve main columns, and after comments and modifications by the other designers, engineering, procurement and legislative preparations began in earnest.

The Conservative UK government at that time perceived the project as a temporary event, a sort of nationwide party, and the designers were under strict instructions not to spend any money on features that would give the building a long-term life. However, they questioned the ecological and economic rationality of this decision, and therefore obtained quotes for higher specification PTFE coated fabric as well as making sure that longer lasting galvanising would be used on the cables. The Labour government, elected in May 1997,

Figure I.38 UK Millennium Experience Dome.

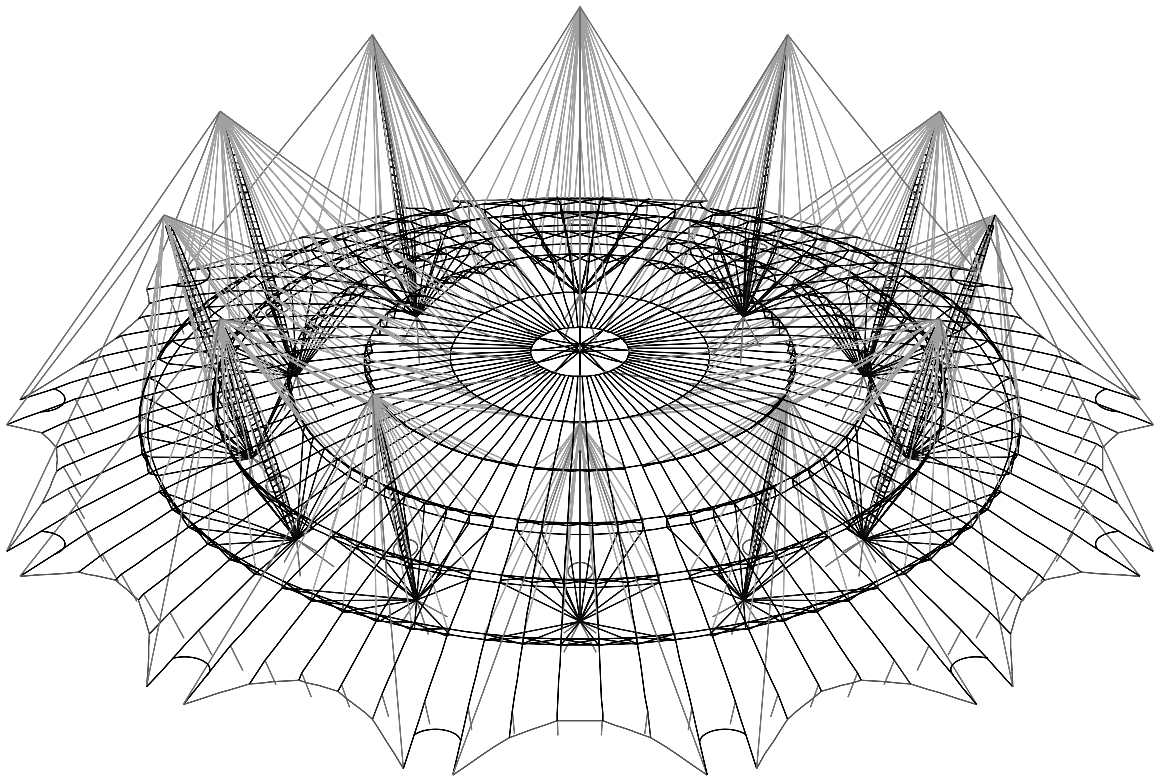

Figure I.39 UK Millennium Experience Dome, isometric computer drawing.

backed the Millennium Experience project they had inherited, but also underlined its value as an urban regenerator for the surrounding area and as a longer term investment in building and communications infrastructure reinforcing the designers' earlier commitment to a responsible building strategy.

To say the dome is big is an understatement – 320 metres in diameter, over 100 metres to the top of the masts and more than 1000 metres around its circumference. The enclosure takes the form of a spherical tensioned fabric cap. This skin is supported by tensioned steel cables arranged radially on the surface of the building, supported and braced from the columns by hanging and tying down cables at 25 metre intervals. Problems arising from deflections caused by snow or heavy rain loads have been avoided by raising the circumferential cables above the fabric surface so that there is a continuous flow to the giant water run-off collectors. At the perimeter the radial cables have been connected to catenary cables fixed to twenty-four external anchorage points. The central 'eye' of the dome is a 30-metre diameter cable ring containing 500 square metres of openable roof lights, which aid the extract fans in the centre of each mast to ventilate the building. The design of the cable and fabric structures were verified using Buro Happold's in-house 'Tensyl' programme, initially using published wind load data which was later confirmed by wind tunnel testing. For safety reasons the structure has been designed to tolerate significant accidental damage; for example, the support pyramids for the masts can remain standing on just three of their four legs.

Only a small proportion of the twelve masts are visible as they plunge skyward through the roof. A myriad of internal cables spring from just above the dramatic 10 metre high pyramidal bases to raise them out of the way of the exhibition structures. It is clear that these cables tension the skin, but their fineness means that they do not obscure the view at all. The huge masts define the vast column free space of the central area, easily large enough to accommodate Wembley Stadium, at that time the UK's national sporting venue. However, it is not just size that impresses, there has been clear attention to detail. For instance, the shape of the concrete column supports and catenary cables restraints have been carefully thought-out, though they are self-effacing and functional rather than wildly expressive. Cable connectors are also engineering rather than sculptural in feel, though

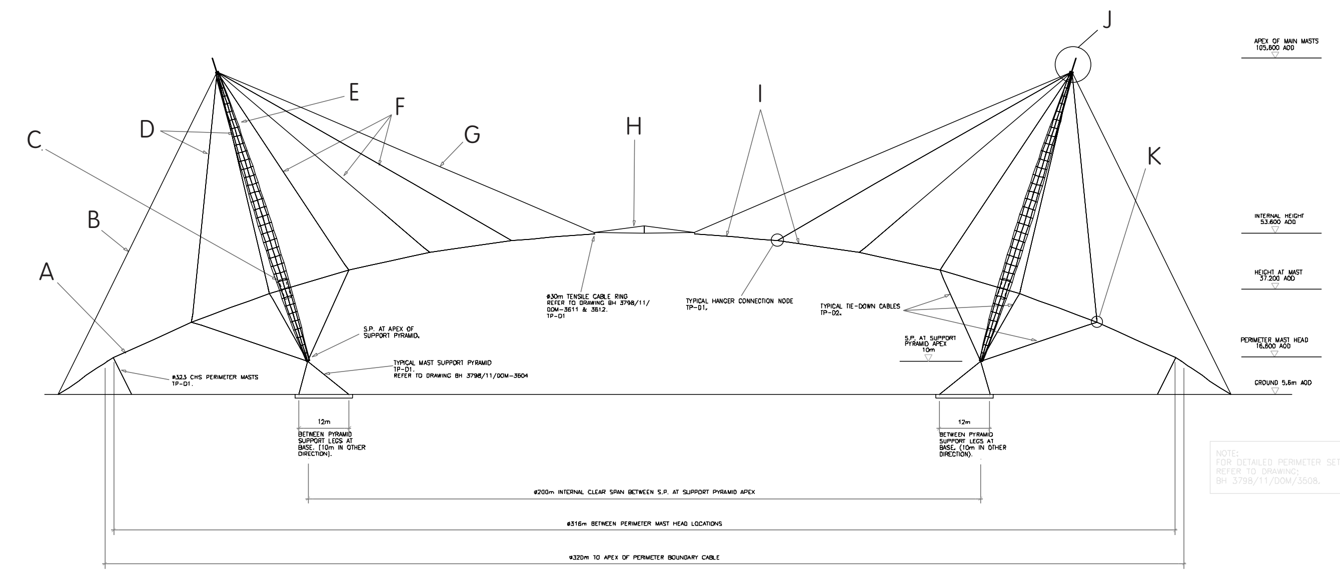

Figure I.40 UK Millennium Experience Dome, section. A, Radial stringer cables continue to ground at 12 No locations around perimeter; B, Typical backstay cable, TP-02; C, Extract fans mounted on mast axis at roof level shown dashed, TP-04; D, Typical hanger cables, TP-02; E, Main steelwork support masts, TP-01; F, Typical hanger cables, TP-02; G, Typical forestay cable, TP-02; H, Central 630-m cable truss independent cladding system; I, Typical radial stringer cables in discrete lengths between hanger connection nodes, TP-02; J, Mast head detail, TP-01; K, Typical hanger tie-down connection node, TP-01.

because they are kept to the most economic size, the distant ones have the visual presence of knots in fine twine. The main radial cable stressing points rest above the perimeter masts in the roof, beneath a contrasting area of bright yellow fabric which accentuates their presence and links them visually to the main columns and secondary structural members which are painted the same colour. The internal service areas that contain mechanical equipment, toilets, restaurants, and hospitality are rational steel and glass orthogonal frame structures, kept simple in order to act as foils to the curving dome and the exuberant exhibition structures that will surround the central arena during the exhibition period. The fabric engineering of the dome utilises self-cleansing, long-life Sheerfill PTFE coated glass fibre material by US manufacturers Chemfab. To avoid the problems of condensation an inner lining called Fabrasorb that has acoustic and insulative qualities has been used.

The Millennium Experience was originally intended on commission to be a series of purely temporary structures. With limited lead-in time, the designers searched for a solution that could be constructed efficiently, erected speedily and would be economic on a cost per square metre basis. Their ambition was to exceed this brief and enclose a vast space with elegance and charisma. Their first-hand experience with lightweight portable structures profoundly influenced the building's design leading to the selection of a membrane clad structure with prefabricated, dry assembled compression and tension components. Furthermore, their proposal opened up the possibility to circumvent the client's initial limitations that the building should be disposable and enabled them to build in features that would ensure that it would have a much longer life. Though this life will probably be on the Greenwich site, it is conceivable that it could also be on another, for the architect asserts the dome is capable of being re-erected elsewhere if this is thought to be desirable.[25] Regardless of the success or otherwise of the exhibition components erected within the dome, and the events that took place there, the building itself is already identified as a physical legacy of this point in the nation's history, much in the same way that the Crystal Palace became a part of Britain's cultural identity in the nineteenth century. The UK Millennium Experience possesses the archetypal image of that quintessential movable pleasure dome the circus – its form, its construction, its structure, perhaps its very existence would not have happened without such historic and contemporary portable architecture precedents. Current detailed proposals for the Dome's future created by sports and entertainments group Anshutz Entertainment Group will turn the building into a 26,000 seat stadium hosting 150 separate events each year, such as awards parties, popular music concerts, and arts festivals.

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An important reason for preparing this book is that the successful manufacture of a high quality building which can move from place to place is a remarkable achievement that deserves detailed examination and communication to a wider audience. Architects, engineers and manufacturers who have undertaken these genuinely innovative building projects have attempted to meet head-on the issues of demanding briefs that require unprecedented performance levels from buildings that move. However, the remarkable standard of technical and operational performance that is sometimes achieved has in many cases been ignored, media coverage tending to explore the novelty value of such projects rather than the lessons they may hold for the industry at large. This is understandable, as portable buildings are of interest in the same way that a prototype car design is of interest – it is a manifestation of contemporary technology to which most people can easily relate. It has a dynamic quality that is of the moment, and imagery that is in turn stimulating and seductive. However, portable building design is different to 'this year's model' in an important way, no matter what the manufacturer's blurb might say, the prime motivations in car design are style and fashion – the prime motivations in building design (though not excluding style, fashion or many other cultural aspirations) are function and continuity. The strategies and techniques which are new to the construction industry and make portable architecture so interesting in its own right, can be tested out here before use in more general situations – the role of such innovation is to enable the design and manufacture of more appropriate, more efficient, more economic architecture that better serves all functions, both temporary and permanent.

In preparing this book I have been fortunate to have had the cooperation of some of the best designers in the world today. Their work in the field of portable architecture is just a part of their design output and I am sure that they would want me to make it clear that there are no boundaries in the sources of inspiration for their buildings. The transfer of concepts between temporary and permanent architecture is an accepted and commonplace part of their design process. The introduction of new types of procurement and construction procedures and the use of manufacturers in different industries are challenging the way that the traditional building industry operates. These designers are invariably knowledgeable about other fields that impact on their own and have built up a network of professional consultants, specialist manufacturers and constructors who have developed the expertise and resources to solve new problems. Their energy, confidence and skill is remarkable and I think it is clear from the projects described here that their work is expanding the thresholds of building design. I therefore dedicate this book to them.

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1 The studies of Amos Rapoport, Bernard Rudofsky and Paul Oliver have largely been responsible for the reevaluation of traditional buildings as worthy of the term architecture. Buildings previously labelled as 'primitive' are now recognised for their finely tuned response to environmental, social and cultural conditions and as precursors to later codified architectural forms.

2 The term 'portable' has been used as a general description for all movable buildings for nearly two centuries and its use in this way is continued here. John Manning, a London carpenter and builder, conceived the 'Manning Portable Colonial Cottage' in 1830 as a prefabricated timber building which could be packaged into a small volume for transportation overseas and assembly at its destination. Between 1895 and 1940 many thousands of mail order homes such as the 'Sears Simplex Portable Cottage' were transported and erected throughout North America.

3 Though not always – the Barrier Reef Floating Hotel is a 200 bedroom building that incorporates a restaurant, kitchen, shops, disco, and bars. Built in Singapore and towed to its site adjacent to Australia's Great Barrier Reef in 1988, it has since been relocated to Ho Chi Minh City, Vietnam. See David Hutton, 'Barrier Reef Floating Hotel', *Process: Architecture*, No. 96, June 1991, pp. 82–87.

4 Disaster relief is often thought to be a major area of use for portable buildings. Though some transportable structures may have a minor role to play in the mitigation of post-disaster shelter problems, the most important factors in preventing suffering and loss of life is political and economic. There is a wealth of experience and research that has dealt with these issues. For an authoritative summary see Ian Davis, *Shelter After Disaster*, Oxford, 1978, or the Office of the United Nations Disaster Relief Coordinator (UNDRO) document, *Shelter After Disaster*, Geneva, 1982.

5 There are some examples of portable architecture not examined here which may be perceived as more important than those investigated (Aldo Rossi's Teatro del Monde, 1979 might be one example). However, such projects have generally been widely examined in journal articles and references have been included in the general bibliography

which includes the main texts that relate to this subject area. For a more detailed bibliography, organised by subject area see: Robert Kronenburg, *Houses in Motion*: *The History, Development and Potential of the Portable Building,* Chichester, 2002.

6 Nearly ten years divided his work on these projects. Thomas first collaborated with Apicella whilst an engineer with Buro Happold. He started Atelier One engineers in 1989. The London office of Whitby and Bird consulted with Mark Bryden, project architect at Nicholas Grimshaw and Partners. The Bath office of Whitby and Bird worked with David Mellor at Alec French Partnership. Buro Happold and FTL have separate origins and after several years close collaboration on specific projects are now once more independent organisations.

7 'The magnitude of the changes in the international order which... are essential may seem impossibly large and quite impracticable to bring about in the time available. However, I think many people underestimate the rapidity with which social changes can occur... surprisingly large changes can become effective surprisingly rapidly when the time is right for them.' C.H. Waddington, *The Man-made Future*, London, 1978, pp. 340–341.

8 Richard Rogers has commented on the new focus for future urban environments: 'Present-day concerns for static objects will be replaced by concern for relationships. Shelters will no longer be static objects but dynamic objects sheltering and enhancing human events. Accommodation will be responsive, ever-changing and ever-adjusting.' Richard Rogers, postscript in Chris Wilkinson, *Supersheds*, Oxford, 1991, p. 111.

9 Hajime Okada, 'Polycastle and Polyconfidence' in *Process: Architecture*, No. 96, June 1991, pp. 106–107.

10 Architect Richard Horden was one of the first to identify the principle of utilising craftsmanship developed in the yacht industry in architectural detailing. See Richard Horden, *Light Tech: towards a light architecture*, 1995. Yacht hull manufacturing technology is used in the construction of Nicholas Grimshaw and Partners' IGUS factory.

11 Other projects have been a mobile restaurant American Diner No. 1, the Slave Trade Memorial at Dakar, Senegal and the Bohen Contemporary Art Foundation, New York, which opened in late 2002. See Robert Kronenburg, ' LOT-EK: Mobility, Materiality, Identity' in Chris Scoates (editor), *LOT-EK-MDU*, Walker Art Center and the Art Museum of the University of Santa Barbara, California, 2003.

12 A prototype is under construction for completion in 2003 by the Walker Art Center and the Art Museum of the University of Santa Barbara.

13 *Progressive Architecture* magazine has been responsible for sponsoring many experimental house designs since the Second World War including the influential house designed by Charles and Ray Eames in 1948. See Robert Kronenburg 'Modern Architecture and the Flexible Dwelling' in Mathias Schwartz-Clauss (editor) *Living in Motion: Design and Architecture for Flexible Dwelling,* Vitra Design Museum, Weil am Rhein, 2002, pp. 18–77.

14 For a more detailed examination of the relationship between technological innovation and housing design see Robert Kronenburg, *Spirit of the Machine: Technology as an Influence on Architectural Form*, Chichester, 2001.

15 For an interview with Sprite Musketeer creator Simon Blackmore see *Immediate 2*, Site Gallery, Yorkshire ArtSpace, 2001, pp. 18–23.

16 See Luca Gazzaniga, 'Mario Botta: Tenda per il 700ºb della Confederazione Elvetica.' *Domus*, March 1991, pp. 1–3.

17 Even stage set design, which has traditionally been concerned with conveying the image of another place, has now been used by Mark Fisher to express architectural ideas about image, technology and form.

18 Buckminster Fuller's 1946 low-cost, factory made Wichita House, for which 37,000 advance orders were placed though only two prototypes were ever made. See Pawley, Buckminster Fuller, Design Heroes Series, London, 1990. Other examples which had limited success are the post-Second World War experimental housing projects, the Lustrund house and the Acorn house, described in H. Ward Jandl, *Yesterday's House of Tomorrow*, Washington DC, 1991. For British experiments in this area see R.B. White, *Prefabrication*, London, 1965.

19 For further information on these projects see Robert Kronenburg (editor) 'Ephemeral/Portable Architecture', a themed edition of *Architectural Design*, September/October 1998.

20 For example, the 'Airtecture' hall was completed for 8% below budget; Powerhouse::UK was completed on time, on budget but with greater operational flexibility than originally envisaged by the client.

21 See Burford, Fish and Smith, 'The Development of a Lightweight Military Shelter' in Robert Kronenburg (editor), *Transportable Environments*, E&FN Spon, London 1998, pp. 158–164.

22 Mark Fisher made this point convincingly during the closing plenary session of the Portable Architecture conference held at the RIBA Architecture Centre in 1997.

23 The PCTC was designed in collaboration with Lawrence Scarpa of Pugh and Scarpa architects, Los Angeles. For more information on OMD'S work see Jennifer Siegal (editor) *Mobile: The Art of Portable Architecture*, Princeton Architectural Press, New York, 2002, pp. 109–127.

24 An extended version of the author's examination of the UK Millennium Dome can be found in the US journal *Fabrics Architecture*, January/February 1999.

25 In an interview with the author in November 1998, Mike Davies of Richard Rogers' Partnership and Ian Liddell of Buro Happold stated that if this were to happen it would most likely be in about twenty years time when the renewal of the membrane would be under consideration and the urban regeneration role was complete.

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PART 1
Role Models

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CASE STUDY 01

IBM Travelling Exhibition Pavilion

Date: **1982–1984**
Client: **IBM Europe**
Architects: **Renzo Piano Building Workshop:** Renzo Piano, Shunji Ishida, Allesandro Traldi
Engineers: **Ove Arup:** Peter Rice, Tom Barker
Contractor: **Calabrese Engineering SpA, Bari, Italy**

The title of Renzo Piano's practice – the Building Workshop – is particularly appropriate for a design team who have been described as remarkable for their lack of professed theoretical standpoint. Piano himself has described his own primary concern with architecture as the method of making buildings, and he looks to materials, techniques and the programmatic elements to guide his formal and logistical approach to the creation of architecture. The early building for which Piano is best known is the Centre Georges Pompidou, built in Paris between 1971 and 1977 and designed in partnership with Richard Rogers and engineer Peter Rice. Though Rogers' subsequent work has obviously continued to develop the theme of technological expression that the Pompidou explored, Piano's architecture has been much more diverse and is

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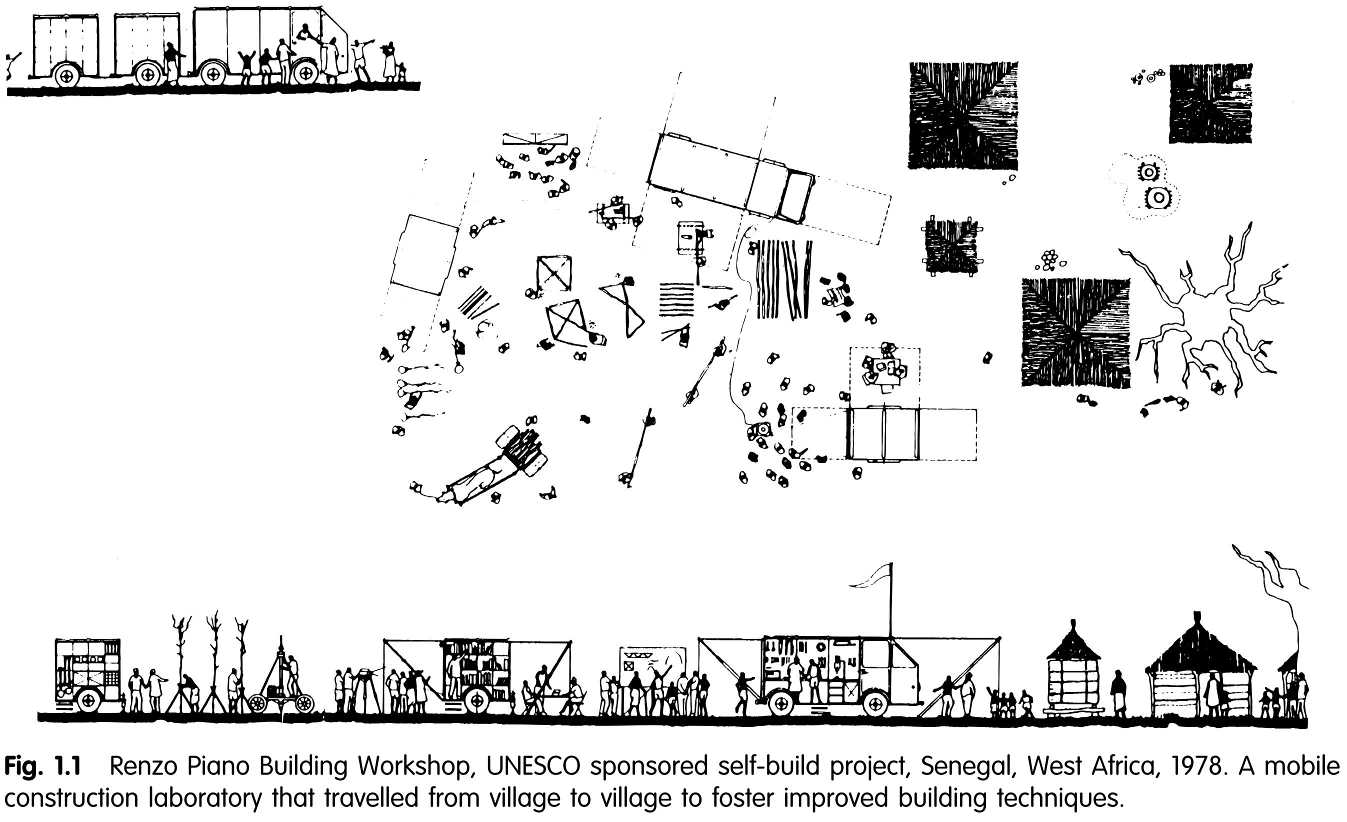

Fig. 1.1 Renzo Piano Building Workshop, UNESCO sponsored self-build project, Senegal, West Africa, 1978. A mobile construction laboratory that travelled from village to village to foster improved building techniques.

characterised by distinctive thematic differences that have shaped each individual project. Despite this diversity a common philosophy can be perceived. Though the projects do vary considerably in their constructional, structural and formal approach, upon close examination several consistent factors can be identified. There is a persistent technological approach throughout the work that indicates an awareness of the opportunities that the application of contemporary materials and techniques has to offer. This does not mean that every project in which the practice is involved incorporates cutting-edge technology but rather that where appropriate, innovation is explored for the opportunities it provides. It also does not mean that new materials and techniques are used to the exclusion of traditional or conventional systems. In much of Renzo Piano's work contemporary technology is used in partnership with more conventional systems, and in this way both may be used to the best advantage. This employment of a pragmatic design philosophy that concentrates on the making of architecture has proven attractive to a wide range of clients who have realised that the diversity of the Building Workshop's projects is indicative of designers who strive to create a dedicated solution to each specific problem. These clients range from the wealthy to those with severely restricted budgets, and from those involved directly with the economic and logistical issues of manufacture to the display and conservation of the fine arts. Piano believes that the wide range of issues such projects generate necessitates an approach that is not restricted by a predetermined architectural ideology.

The Renzo Piano Building Workshop has been involved in many projects for temporary buildings. Piano views impermanent buildings as just another part of mainstream architecture, and his design approach as part of the same discipline. Clearly, all architecture is to some extent temporary, even so-called permanent buildings may not last for very long and the idea of bringing flexibility and long-term adaptability to these structures is important. He also believes that experimental architecture is most commonly realised in response to unusual briefs and these are frequently for buildings based in temporary locations or with impermanent uses.

The practice has also been involved in design activities outside the field of architecture on projects related to vehicle design. Piano is an enthusiastic sailor and has built four yachts for his own use, each utilising a different constructional method. The first used a relatively low technology application of plywood, the second a thin skin plywood construction, the third used ferro-cement and the fourth wooden rods embedded in adhesive.

In the late 1970s Piano and engineer Peter Rice carried out experimental work associated with car and commercial vehicle design. The Flying Carpet was a project to provide a durable lorry for third world countries. Rugged mechanical components would be manufactured in Europe and then shipped out for assembly onto a locally made ferro-cement, flat bed truck frame. Another project was for the giant Italian automobile producer Fiat – the design of a compact four-door saloon that would be lighter and stronger than any other comparable vehicle. The structure was made from a galvanised frame designed to crumple progressively in the event of a crash and the skin was assembled from a series of modular polycarbonate panels. Polycarbonate vibrates at a lower frequency than steel and its use helped avoid resonance with engine and road vibrations and made the vehicle much quieter. It also had the advantage of being non-corrosive and capable of easy replacement. This meant that there was a distinct advantage over unitary construction (which restricts the shape and function of a vehicle to that determined by the factory production line) as the body shape could be modified with relative ease – even by the owner as his load-carrying requirements changed.

The Building Workshop's most prestigious vehicle design project has been their work on the P&O cruise ship, the *Crown Princess*. The basic hull shape and engineering design was carried out by naval architects – the Building Workshop were retained to contribute to the image of the ship, generated primarily through shaping its external appearance and designing the public rooms. The ship (along with its later identical sister ship the Regal Princess) was built at the shipyards of Fincantieri near Trieste in Italy between 1987 and 1990. At over 70,000 tons, the ship is 246 metres long, 32 metres across the beam and has a total of 50,000 square metres of accommodation on thirteen decks. The 1750 passengers are accommodated in 798 cabins with additional berths for the 656 crew members. Such statistics put into perspective the achievement that such floating 'buildings' represent. Despite the engineering achievement of these ships, many people believe that economies in construction have meant that these new ships do not have the beauty of older ocean liners. The adoption of repetitive, slab-sided construction has

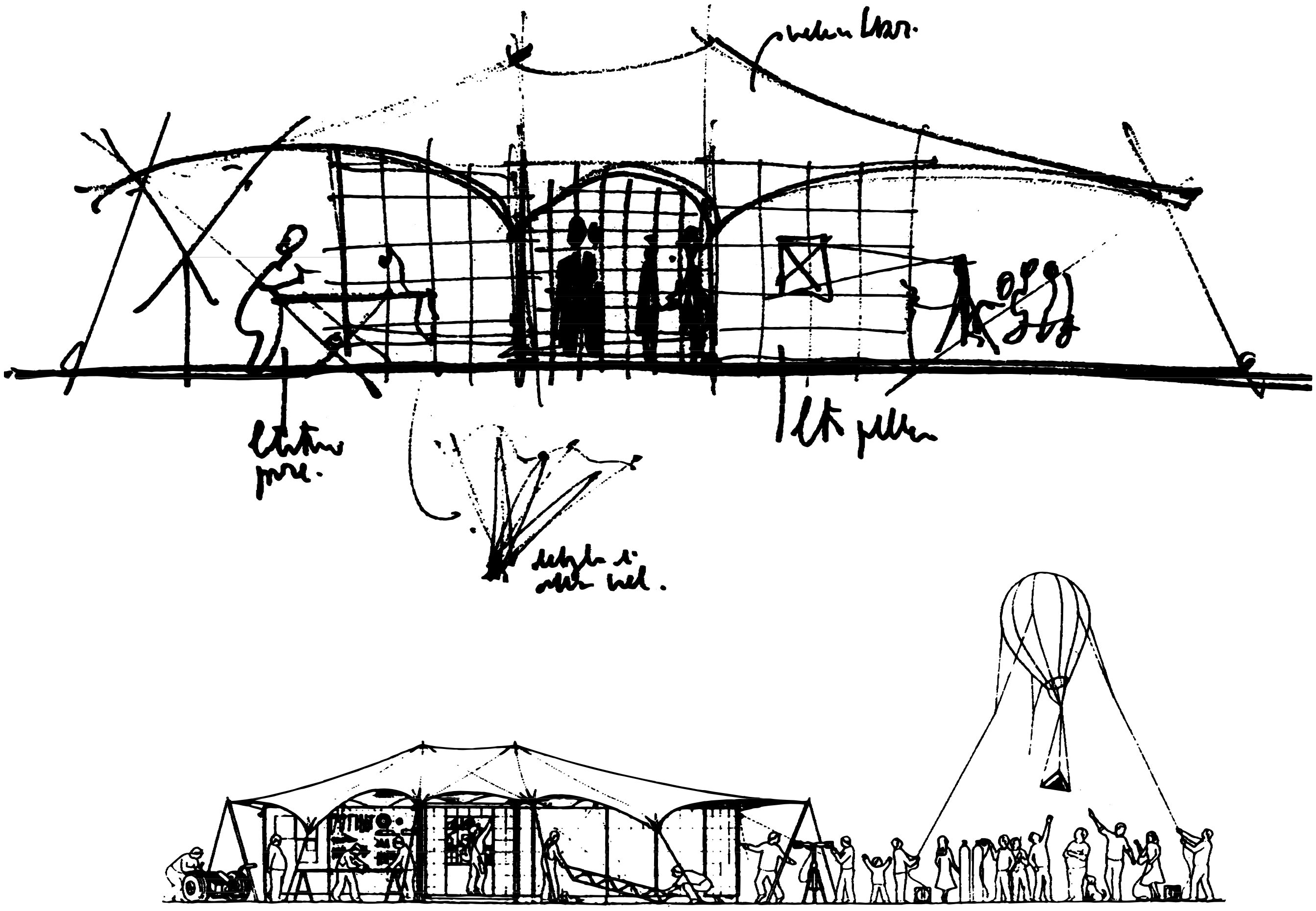

Fig. 1.2 Urban renovation pavilion, 1979, Renzo Piano Building Workshop. Conceptual and presentation design drawings.

led to modern ships' construction being based on a continuous extrusion with a pointed section at the bow. Piano not only wanted to reintroduce some of the grace and organic, sinuous quality of the earlier ships, but also to design dynamic external forms that would create dramatic internal public spaces.

The design team's response was to create a domed observation lounge which changed the ship's profile. The space was created with a rib-cage like structure that introduces the idea to the passenger of being inside a giant marine creature rather than a piece of man-made engineering. In order to achieve an acceptable centre of gravity, the upper bridge of the *Crown Princess* utilises a new method of bonding aluminium to steel which involves controlled explosions that fuse the materials together. Despite such innovations, Piano was unhappy about the final result of the work on the *Crown Princess*, as, although the vessel exhibits undoubted engineering achievements, restrictions placed on the design by a combination of marketing and insurance requirements meant that the full possibilities of technical and spatial innovation were not explored. The relative conservatism of marketing executives also prevented the Fiat prototypes from being put into production. Paradoxically, it is therefore in Renzo Piano's work on projects with more modest budgets that the most innovative mobile structures have been realised.

The range of temporary building structures that have been designed by the practice is wide – from relatively high-budget cultural buildings like the Italian Industry Pavilion at the Osaka Expo of 1970 to the minimal cost UNESCO travelling self-build mobile construction unit of 1978 (see Fig. 1.1). The former was designed to express the sophisticated technological capabilities of Italian industrial production, the latter to be an enabling facility

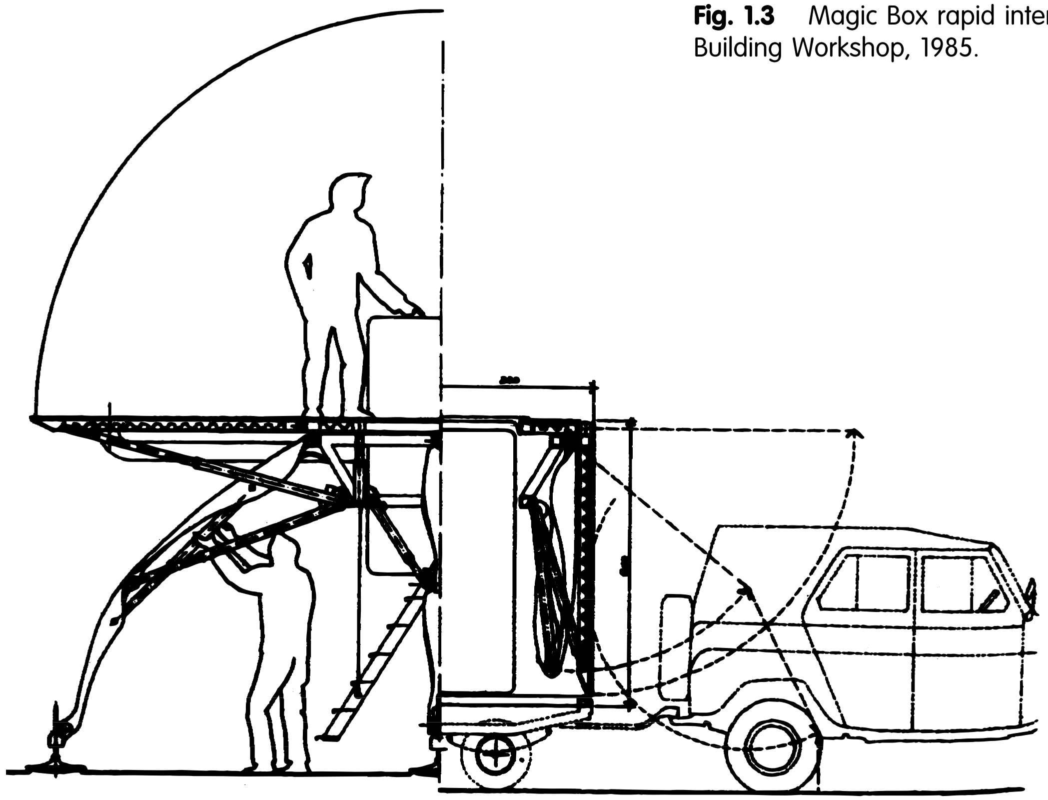

Fig. 1.3 Magic Box rapid intervention unit, Renzo Piano Building Workshop, 1985.

transported directly to a West African rural population to help them construct their own buildings by adapting local materials using vegetable fibre and mud.

In 1979 Piano began an urban reconstruction project in Otranto in southern Italy to renovate the historic town centre buildings without loss of their urban character and identity (Fig. 1.2). The buildings were in poor condition, had inadequate hygiene facilities and were in need of total renovation, however, large-scale work by professionals would not only be costly but would result in significant urban upheaval as large numbers of people left their homes and place of work to allow major contracts to take place. The solution was to encourage the 'gentle' restoration of the properties, often by the occupants themselves whilst they remained in their houses. Piano created a mobile laboratory that could be set up in any small public space right at the heart of the reconstruction area. The structure was housed in a cubic container that could be transported on a small truck with an integral crane. At its site, the cube was unloaded onto the ground and panels unfolded from the walls to form enlarged external exhibition spaces and meeting places. Furniture was transported within the cube. A membrane roof was stretched over the entire space and tensioned with poles and ropes. The now empty interior of the cube was used as an office and the exterior became a continuously open exhibition of renovation and conservation techniques and a focus for gatherings with the local population. The success of the Otranto project led to Piano's team being asked to work on other urban reconstruction projects in Venice, Genoa, Bari and Matera.

The Magic Box (1985) was a project to design a rapid intervention unit for disaster situations based on Piano's experience in third world countries (Fig. 1.3). The brief was to create a communications and monitoring facility that could be instantly and easily deployed without the use of excessive resources, and be totally independent once it had reached its destination. The basic facility was to be transported within a 2.4 metre cube that was small and light enough to fit into an aircraft or be towed behind a small vehicle. Once at its destination, 'legs' could be deployed from the side of the unit (using geometries based on the movement of an insect limb) to stabilise a 36 square metre raised platform fitted with a tensile shelter membrane. The pod at the centre of the unit was to contain the communications and analysis equipment and a small power plant to support its operation.

IBM Travelling Pavilion

The most famous and the most important of Renzo Piano Building Workshop's mobile building projects is the exhibition pavilion created for IBM's tour of European cities between 1982 and 1984. The brief was to create a venue that could be used to communicate the developing power of computer technology in a direct, hands-on way. IBM is proud of its reputation as a company that produces such high-quality equipment that it is acknowledged as an industry standard. Their philosophy in the commissioning of buildings is similar, and high-quality discreet structures by designers such as Arup Associates and Norman Foster have been built in the UK. Their travelling pavilion was to communicate the quality and usability of their computers but was not to be a sales room. The venue was to take advantage of parkland sites in city centres and should therefore give visitors the impression of being close to nature despite being enclosed within a building that contained the latest technological equipment available. This apparent dichotomy between the technologically advanced equipment that formed the basis of the exhibition, and the natural qualities of the sites to be used, generated one of the most interesting aspects of the designers' solution. How could a building convey the high-technology characteristics of its contents whilst directly relating to elements in nature and still accommodate the complex constructional problems of a completely portable structure? Clearly it is not possible (nor desirable?) to completely separate computers from the mystique of high technology, however, by placing them in an environment that appeared to utilise natural elements for its inspiration, and removing them from laboratories and into the public park, it subtly influenced the common perception of them being remote tools for specialist use.

Renzo Piano worked with Building Workshop partner Shunji Ishida and Ove Arup engineer Peter Rice to create a solution that responded to all these complex issues. The pavilion consisted of an 85 metres long, 480 square metre semi-circular tube that contained all the servicing required for the facilities to operate independently of mains supply, day and night (Figs 1.4 –1.6). The structure was based on a suspended steel floor that contained a hollow space for services. To this was attached a series of free-standing three-pin arches fixed to the edge of the floor at their base, and above the centre

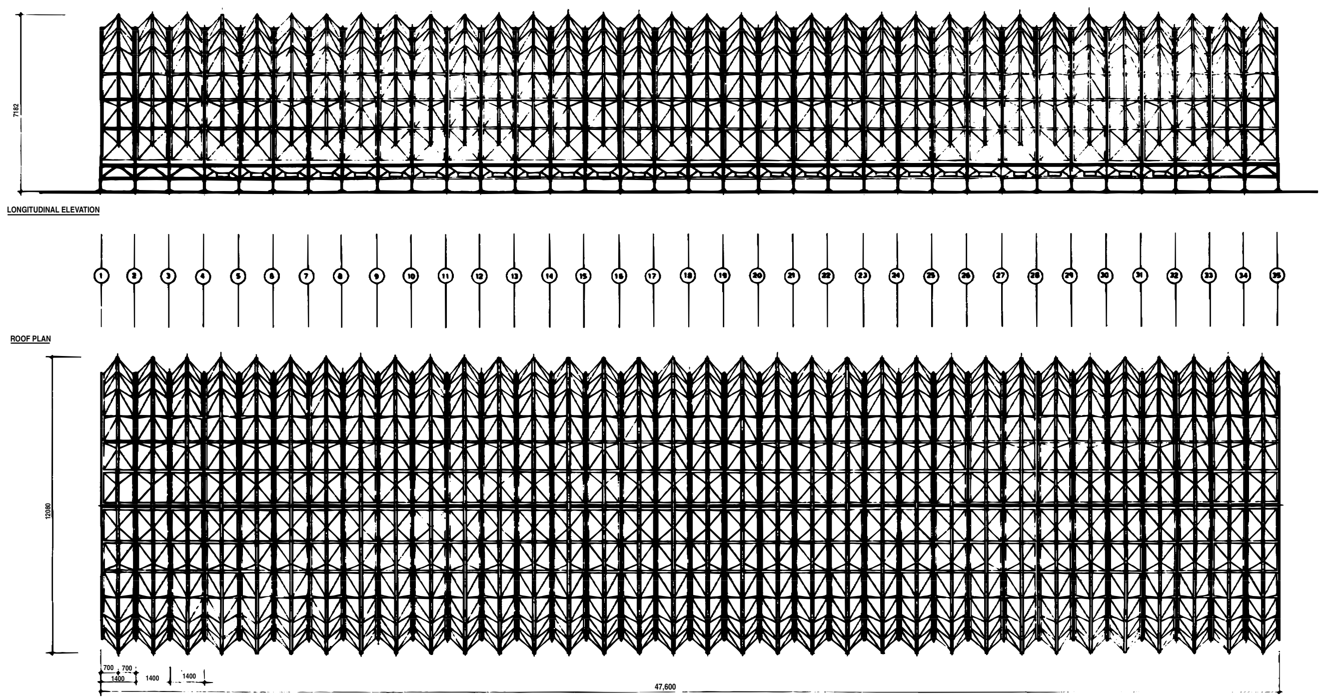

Fig. 1.4 Elevation and roof plan of the IBM pavilion, 1983.

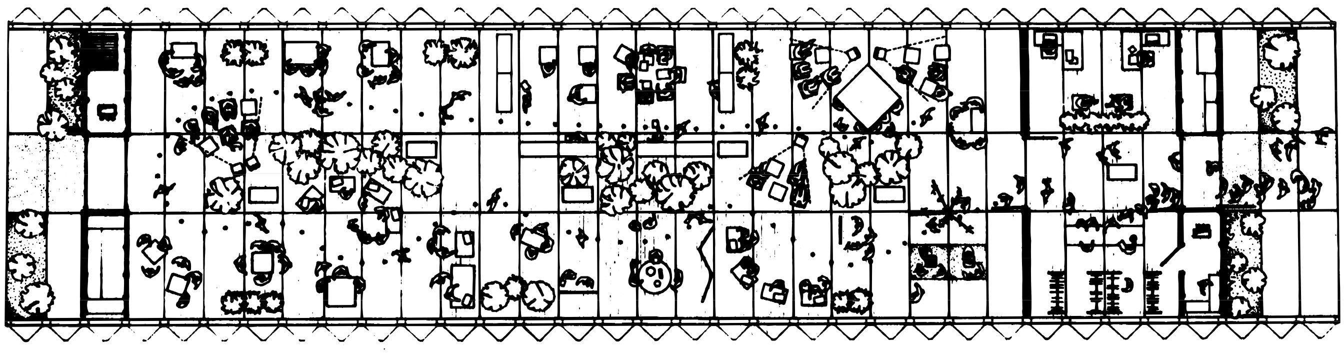

Fig. 1.5 Plan of the IBM pavilion. From right to left: entrance, cloakroom and administration, main exhibition space, storage.

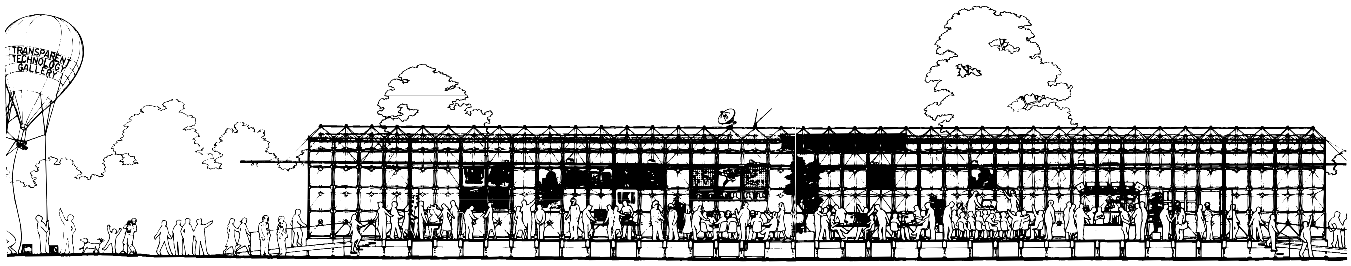

Fig. 1.6 Long section, IBM pavilion.

of the space at their apex. The two segments of each arch consisted of an ingenious structural system that incorporated traditional and modern materials used in conjunction, to give an organic yet technological image. Each segment consisted of six polycarbonate pyramids (manufactured and fitted in units of three) fixed at the point and the rim by cast aluminium joints to laminated timber (larch) booms. These transparent pyramids therefore formed not only the structural connection that made up the arch but also the skin of the building. Neoprene gaskets and adjustable stainless steel rods were used at connection points to allow for differential movement between the various materials, and also to accommodate the flexibility required in the setting up and dismantling of a portable building (Fig. 1.7).

The assembly procedure began with the arrival on site of the twenty-three bright yellow IBM trucks used to transport the facility. These trailers were customised alterations of standard vehicles and were made by the project fabricators and erection team, Calabrese Engineering. Twenty-one of the trailers contained the building in componentised form, the internal equipment and furniture. The remaining two contained the mainframe computer and the chilling plant for the air-conditioning system (Fig. 1.10). The components were unloaded and moved around the erection site with the use of a fork-lift truck, hired separately at each location. Despite the building being supported on adjustable jacks with spreader feet, where soft grass ground conditions prevailed, a concrete strip foundation pad was installed (see Fig. 1.8). After the steel floor structure was erected, arches were assembled on a working surface laid out near the site (Plate 2). The central parts of the timber ply floor panels were placed in position to make a working platform for the erection of the arches by a team of three riggers. One arch was connected at its bottom edge and the top edge elevated into position with a pneumatic tool. The second arch was fixed at its bottom edge on the opposite side of the floor and its top edge elevated to meet the other where they were bolted together at the apex by a rigger standing on a ladder (Fig. 1.9). When the arches were erected, the rest of the floor could be put in place and the end walls of steel frame and wood panel construction installed. The main interior space enclosed all the exhibition displays and working machines in an environment that also contained large natural plants to complement the trees which were clearly

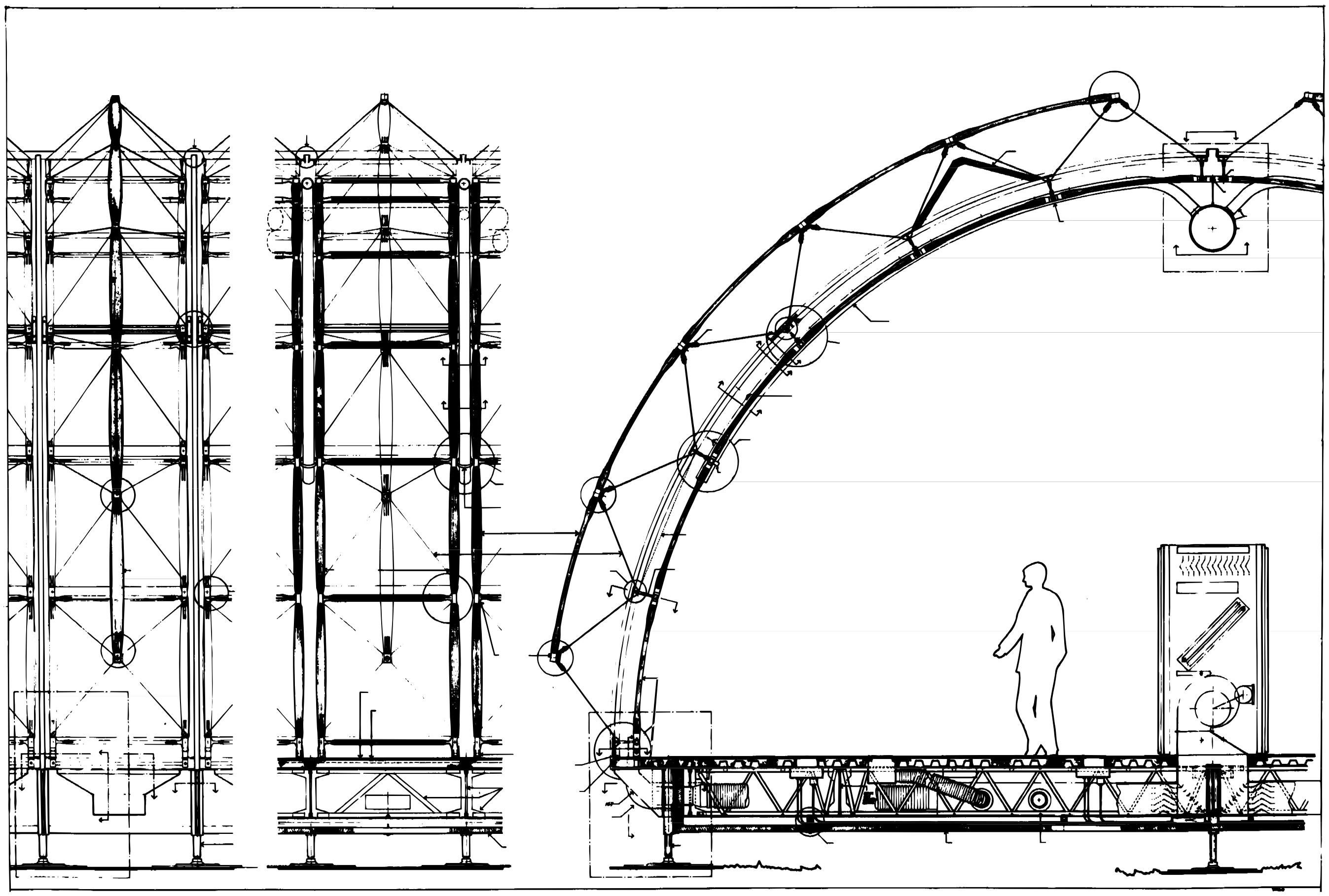

Fig. 1.7 Detailed cross-section and part elevation, IBM pavilion. The sub-floor area contains services including ducts to the central air-conditioning unit.

visible outside. Visitors entered up a ramp into a foyer space that contained a cloakroom and offices. As the building stayed on each site for up to two months, site preparations were sometimes made that included landscaping and approach paths.

Because of the delicate equipment it contained, it was necessary that the building include sophisticated environmental conditioning so careful attention was paid to the operation and placing of services. In certain seasons a transparent building would overheat badly, though in the London exhibition which was held during November and December, cold and moisture would have been the problem. The building therefore incorporated a number of passive and active environmental control features. Two forms of additional layering could be added to the internal structure – opaque insulating panels made from perspex that could be fixed into the polycarbonate pyramids, and fine aluminium mesh shades that could be attached

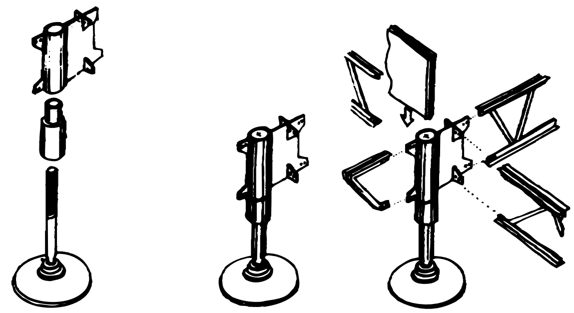

Fig. 1.8 IBM pavilion, adjustable leg detail.

across their base. These were supplemented by tensile shading membranes that hung within the space and reduced glare on the computer screens. Active environmental modification consisted of air-conditioning units placed down the centre of the building which extracted used air and replaced it with fresh chilled or heated air, pumped in through

Fig. 1.9 Mounting of a prototype arch for Renzo Piano's IBM pavilion.

floor grills. Condensation was prevented from forming on the skin by pumping warm air down a central duct beneath the apex and distributing it against the arch walls using aircraft-type nozzles pointed at the polycarbonate pyramids. The trailer that supplied the power for heating, chilling, lighting and computing equipment could be situated as much as 80 metres away from the pavilion. The entire exhibition could be erected in three weeks and, as with many travelling performance events, two separate buildings were made so that one could be serviced whilst the other was in use.

The success of the IBM pavilion was such that four times the number of people predicted visited it at each site and in 1986 the design team were asked to prepare a design for a second pavilion. Though this was never built it is interesting in that a completely new concept was explored based on the form of a Ladybird insect. This pavilion was smaller than the earlier building and care was taken to simplify the erection process. The main structure consisted of an aluminium and laminated timber frame that, when erected, formed a spherical dome which supported a three-layer flexible skin, stiffened during erection with carbon-fibre tubes.

The IBM pavilion was a building of great complexity which exhibited in its design a sophisticated understanding of structural and environmental concerns. Something further away from the common perception of a portable building as a Portakabin or a tent cannot be imagined. It challenged the idea that temporary buildings have to be simple and concentrate so much of their budget into solving pragmatic assembly and deployment problems that there is nothing left to make the architecture. Despite its significant presence as a building, it can also be perceived as a piece of sophisticated product design – an object that crosses the boundaries between different applications – appropriately, in the same way that the same computer hardware can be used for many different tasks. The building became an exhibition tool in itself, displaying the concerns of the manufacturer as well as the products within.

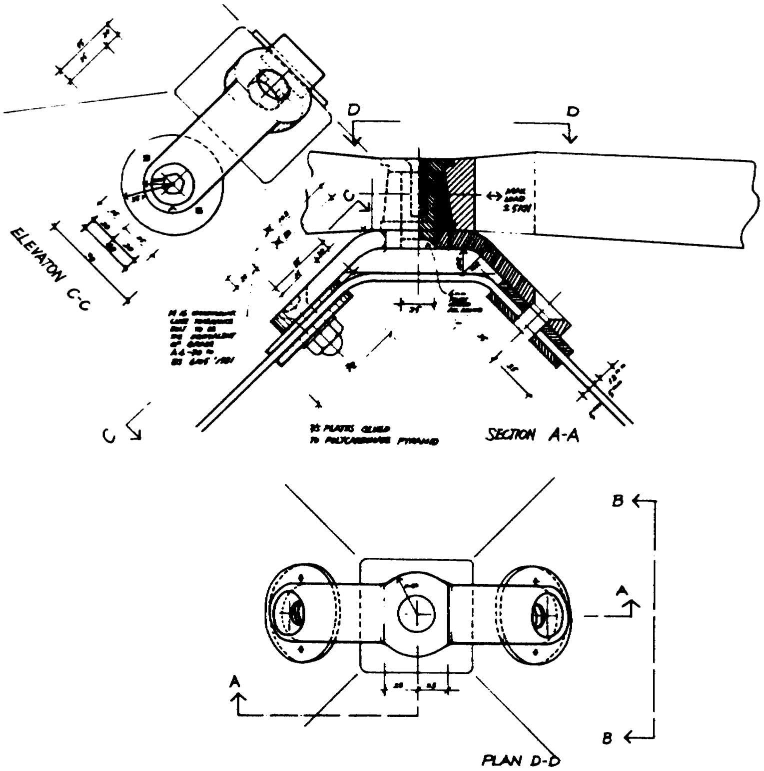

Fig. 1.10 The laminated timber ribs are fixed to polycarbonate pyramids via an adjustable stainless steel rod. This affords flexibility during erection and thermal movement.

Fig. 1.11 IBM pavilion and one of its service vehicles.

The pavilion was a man-made form that was designed to be placed in a natural landscape (Fig. 1.13). It merged into its sites to a certain degree because of its cellular, organic form and reflective skin, however, there is no doubt that its dominant image was as an example of contemporary technologically based design. The modular nature of its construction was clearly expressed in its form and utilised in its manufacture and erection, yet this did not result in a mechanistic, repetitive structure but one that used the contrast of solidity and transparency to reflect natural light and the external features of the site to its best advantage. The positioning of this sensitively designed visitor to historic sites adjacent to Alfred Waterhouse's Natural History Museum in London, the remains of St. Mary's Abbey in York, and the Castello Sforzesco in Milan (Plate 3) resulted in dynamic and stimulating contrasts not usually found in the built environment. The logistical strategy that this building employed clearly exhibits one of the most significant advantages that portable architecture has – the capability to be placed in important and sensitive locations (Fig. 1.11). The advantages to a client such as IBM, who wished to communicate the qualities of their products to as many people as possible in a direct and exciting way, are clear. The advantage for the development of modern architecture is that it is seen in relation to other types of buildings in a favourable way, responding both to the natural environment and acting as a foil to

Fig. 1.12 Mobile buildings can utilise famous landmarks as a temporary 'address'.

Fig. 1.13 IBM pavilion external skin.

Fig. 1.14 Interior space. Natural materials and internal plants reinforce the connection with the outside park environment.

its historic, man-made setting. Buildings of quality such as this prove that modern architecture can possess distinct, quantifiable advantages that if used appropriately are suitable for many settings and applications.

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Karaza Theatre, Sendai and Tokyo, Japan

CASE STUDY 02

Date: **1987–1988**
Client: **Kara Juro and Seiyo Corporation**
Architect: **Tadao Ando Architect and Associates:** Tadao Ando
Contractor: **Tobishima Corporation, Japan**

As with many of the manifestations of its culture, Japanese architecture is a result of different concerns to those found in the West. Religion, philosophy and the relatively isolated political and social history of Japan have uniquely shaped recent architectural development. Before the nineteenth century, Japan endured a self-imposed exile from the rest of the world for more than 200 years. During this period a pattern of traditional architecture developed that cultivated meditation and prayer, and celebrated concepts of serenity, simplicity and closeness to nature. Paradoxically, these pure traditional forms only became attractive to Western eyes in the twentieth-century search for a new modern architecture. After breaking a blockade by America in the Meiji period, Japanese society underwent a dramatic

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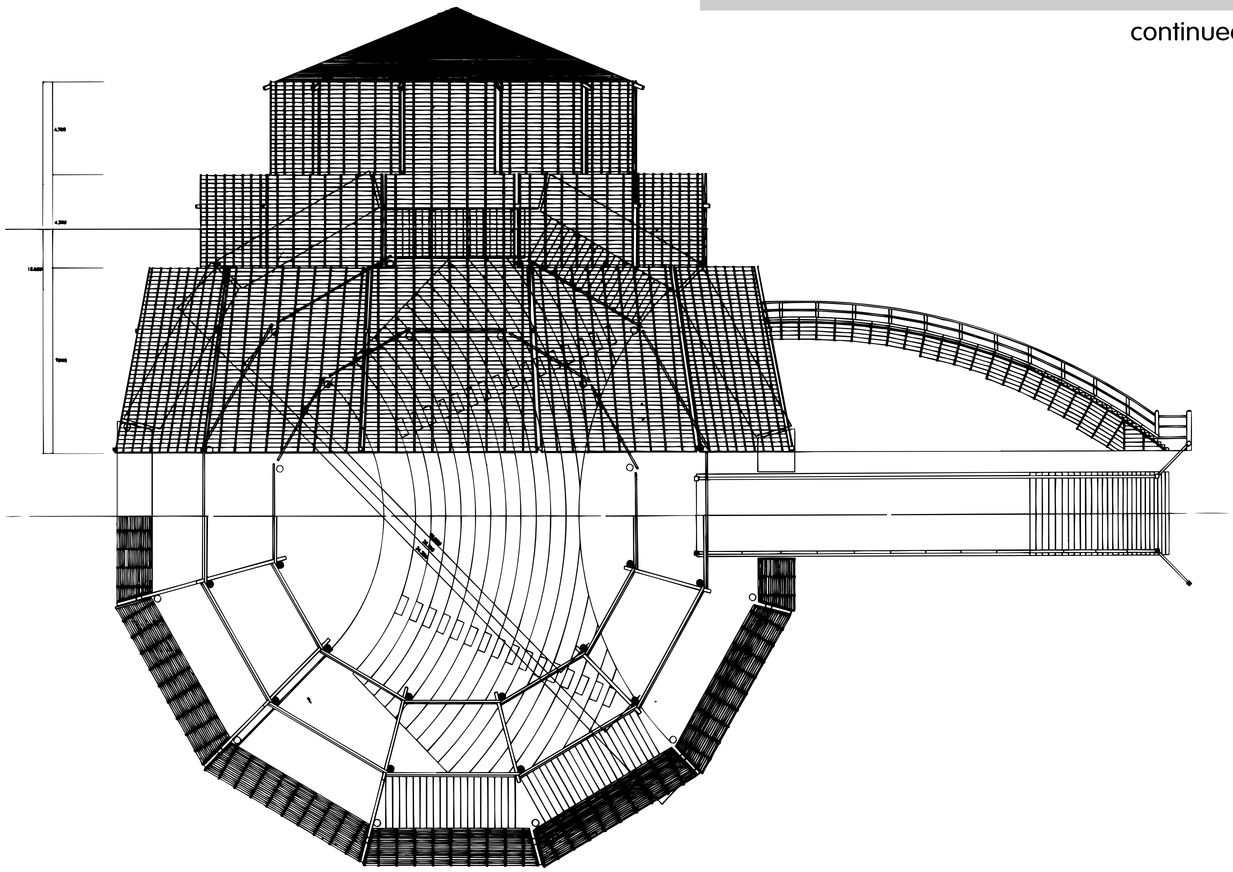

Fig. 2.1 Karaza Theatre, Tadao Ando, 1987–88. Plan and elevation.

upheaval based on the adoption and adaptation of Western commercial enterprise. To a lesser extent Western customs and ideals were also adopted, though not to the exclusion of traditions from the country's own past. Fantastic commercial and industrial success resulting from the rebuilding of the country after the Second World War led to dramatic growth and the establishment of Japan as a world economic power. It also provided the financial capacity not only for extensive investment abroad but for unprecedented property development at home. The incredible economic situation that led parts of down-town Tokyo to be valued at £150,000 per square metre meant that construction costs became in comparison a relatively small percentage of the overall budget. Architectural experimentation with access to generous budgets became part of the highly competitive development scene.

Another factor in this building boom was that due to development economics and changing planning rules, buildings became more and more temporary in their occupation of a particular site, often being demolished to make way for new developments after only a few years. However, temporary buildings are also an integral part of Japanese culture. The essence of ascetic Shintoist philosophy which pervades Japanese existence is that it is not the permanent elements of life that are revered but the spiritual renewal represented in the periodic cycles of death and rebirth, destruction and recreation. Ancient revered temples such as the Shinto Ise Shrine are the equivalent of the great cathedrals of Western Christianity which were built to last for thousands of years. However, the Japanese Shinto shrines are carefully rebuilt to their original pattern every few decades.

Another factor of Japanese culture is the importance of tradition which pervades many aspects of everyday life and has even been adopted into industrial and commercial activities. The new generation of post-war architects, therefore, still retain a deep involvement with the traditional elements of Japanese design which includes building materials and the influence of natural environmental elements in their design. In the same way that the Japanese have totally accepted and synthesised modern technology such as electronics and communication technology into their society, so Japanese architects have adopted modern materials like concrete and steel and endowed them with characteristics that relate to their natural predecessors such as stone and timber. Toyo Ito's projects Egg of the Winds (1986) and the Tower of the Winds (1989) translate the speed and direction of the wind, a natural phenomenon that is revered in Shinto and Buddhist philosophy, into video projections and illuminated neon displays, and in the ceiling of his Nomad Club (1986) in Tokyo he used perforated metal screens shaped to represent wind-blown fabrics. The dwellings designed by Riken Yamamoto at the Rotunda Building in Yokohama (1987), though built of steel and glass, convey the same lightweight, translucent feel of traditional houses which incorporate sliding paper panels and a jointed wooden frame. Tadao Ando refers to concrete as an 'authentic' material, often using it in a constructional grid made during casting. Despite its manifestation in modern materials and techniques, this grid relates in size and form to a nominal 1.8 metre by 0.9 metre rice-straw tatami mat, which is in turn the basis for the 1.8 metre square tsubo, the traditional method of measurement for Japanese buildings.

This feature of Ando's work relates to another aspect of traditional design principles that are employed in contemporary Japanese architecture, that of geometry. The use of the tatami as a basis for planning and design results in geometric patterns and modules that are an inherent part of the formal generation of traditional architecture which have now been incorporated into the modern.

The Karaza Theatre

These aspects of tradition in modern Japanese architecture – the temporary nature of Japanese building, the continuance of the spiritual aspects of Japanese culture in contemporary building, the utilisation of natural elements or materials, and the application of geometry in the generation of architectural form – are all present in the Karaza Theatre, a temporary building designed by Tadao Ando between 1985 and 1987.

Tadao Ando was born during the Second World War and is one of the second generation of Japanese post-war designers whose work has followed on from architects like Kisho Kurokawa who were the first to establish a definitive modern aesthetic in the 1970s. Ando did not have a conventional training and instead combined a highly individual course of personal research coupled with extensive travel in the West and a brief career as a professional boxer. He was greatly

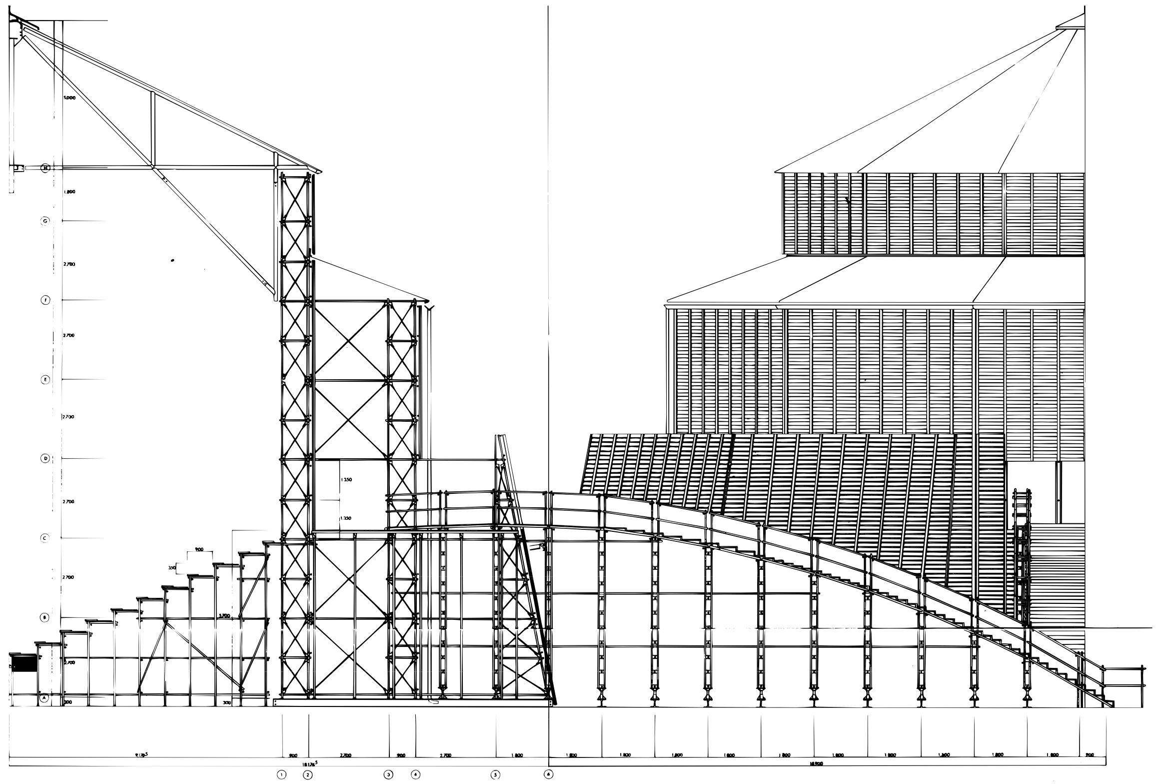

Fig. 2.2 Section and part elevation. The main structure is made from standard scaffolding. The roof utilises a lightweight transportable steel structure.

influenced by Le Corbusier, Louis Kahn and Carlo Scarpa and the early work with which he gained his reputation consists of precisely controlled houses that synthesise an international style modernism with a more spiritual Eastern sensitivity. Even though these buildings were generally constructed of concrete, Ando still refers to the skill of the master carpenter in the permanent impression of the carefully crafted temporary timber shuttering used in their construction.

The Karaza Theatre was designed for the travelling avant garde theatre/performance company led by Kara Juro who up to that time had used a red tent for their events. Despite the innovative nature of Juro's work, tradition also plays a part. The company used a stage area that consisted of a small raised platform divided by a symbolic river, a stylised version of the performance set used for traditional Japanese comic and tragic theatre. The original concept for the Karaza building was for a wooden structure with the image and form of a watchtower that would be sited at Asakusa in Tokyo (Fig. 2.1). The building would be constructed entirely of timber which Ando describes as an 'eternal' material. This may seem paradoxical to Westerners as it can be destroyed much more easily than other materials such as stone; however, as timber is a natural growing product, this perception relates to its constant renewal.

When the brief was changed to the idea of a moving building, the form remained but the main structure was altered to a system that could be erected and dismantled easily. Rather than design a dedicated system with the resultant dramatic increase in budget, Ando utilised a commonly available form of temporary structure for the main part of the building – scaffolding (Figs 2.2–2.3). This not only had the advantage of significant cost savings but it also meant that transportation costs could be much reduced. By faxing a set of comprehensive instructions the building process could be carried out by local labour in advance of the arrival on site of the theatre company's stage team. Ando's early sketches of the building show it erected in

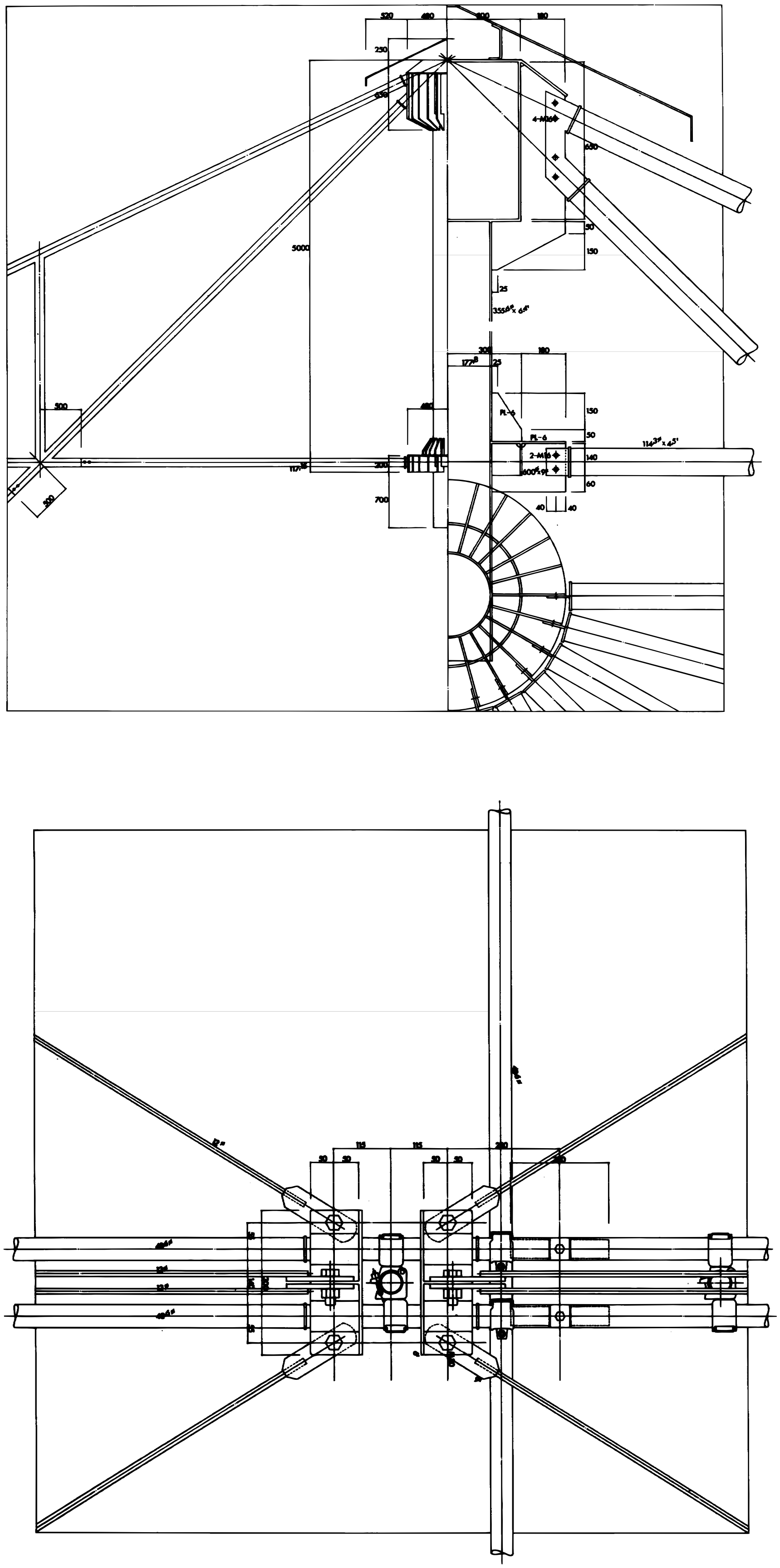

Fig. 2.3 Karaza Theatre constructional details. Top: roof structure, bottom: scaffolding bracing.

dramatic locations such as the harbour front at New York, reminiscent of Aldo Rossi's 1979 Teatro del Monde, a transportable theatre built on a barge and floated from city to city along the Mediterranean coast.

The building's form is a dodecahedron in plan – three twelve-sided extrusions placed inside each other. The largest external form has walls that slope gently inward, the remaining two are vertical. The walls are made from black-stained wooden boards which have gaps between them on the lower outer wall and are solid for the theatre walls. Simple bleacher seating covered with carpet is used for the 600 seats in the auditorium. A staircase rises between the two outer walls following the profile of the building and leading to the elevated main entrance (Figs 2.8–2.9). The main approach to this is via a *taikobashi*, an arched bridge which symbolises the passage from the world of reality to the world of illusion and from the present world to the *higan*, a Buddhist description of the world after death. The twelve sides of the building are intended to represent the cosmos. Built around the entire complex is a traditional fence of woven bamboo called a *takeyarai* used to emphasise the 'other worldly' nature of a space used for theatre. All these symbolic elements contribute to the significance of the building for visitors who are aware of these traditional meanings from the representational elements commonly found

Fig. 2.4 CAD drawings showing the erection process.

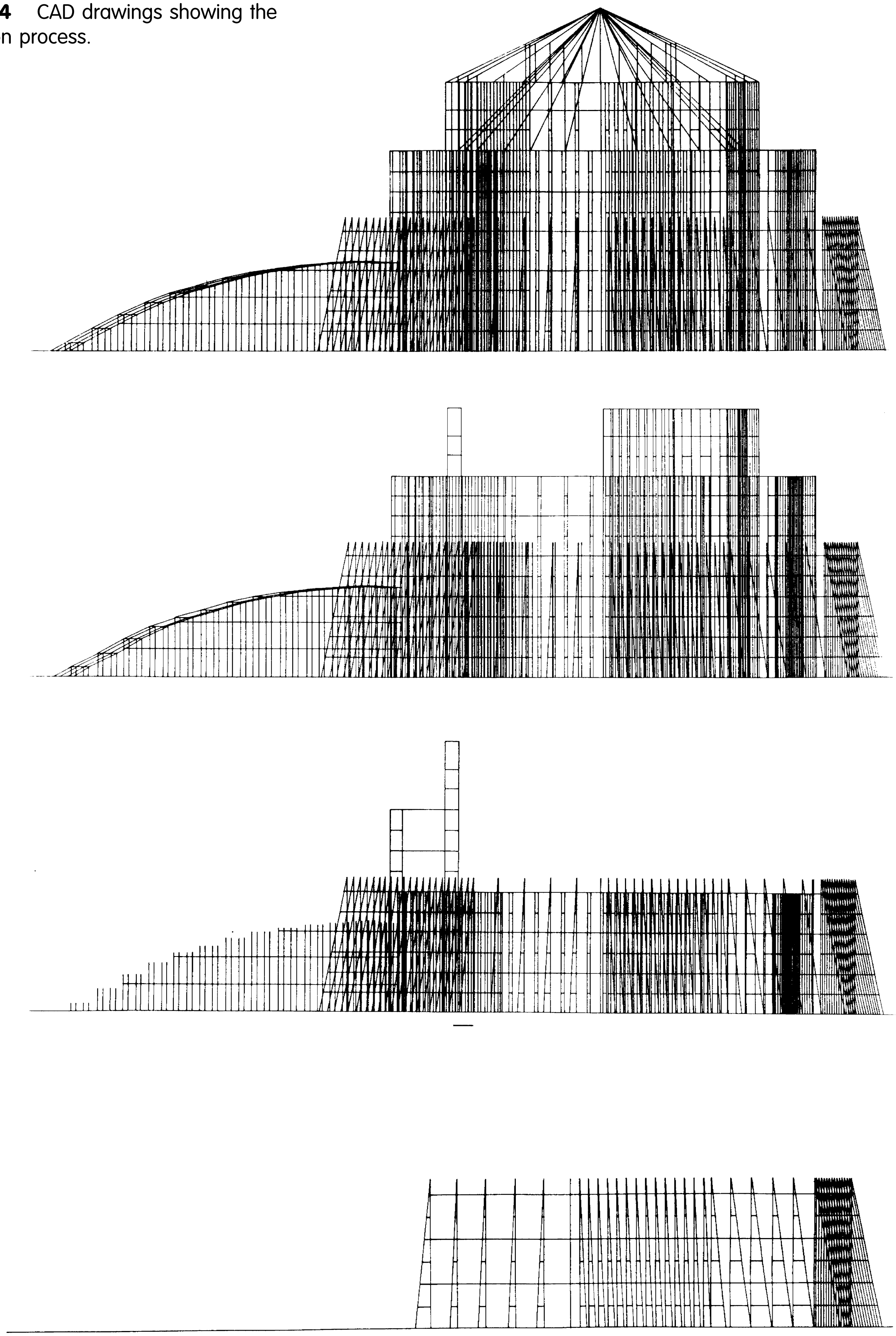

Fig. 2.5 Erection process. The site set out with delivery of scaffolding underway.

Fig. 2.6 Wall structure under construction.

in house and temple architecture. Their application to a contemporary building in no way dilutes this power.

The main building components – scaffolding and timber boarding and bleacher seating – are all made from locally available standard items, though a number of special elements were also transported between sites. The roof was a red-coloured tension membrane, reminiscent of the Juro group's previous transportable shelter, the red tent. This is fixed to a very light steel truss, 27 metres high, which spans the 18 metre wide auditorium space. Rods that firmly brace the inner and outer walls four metres apart and another red membrane roof that

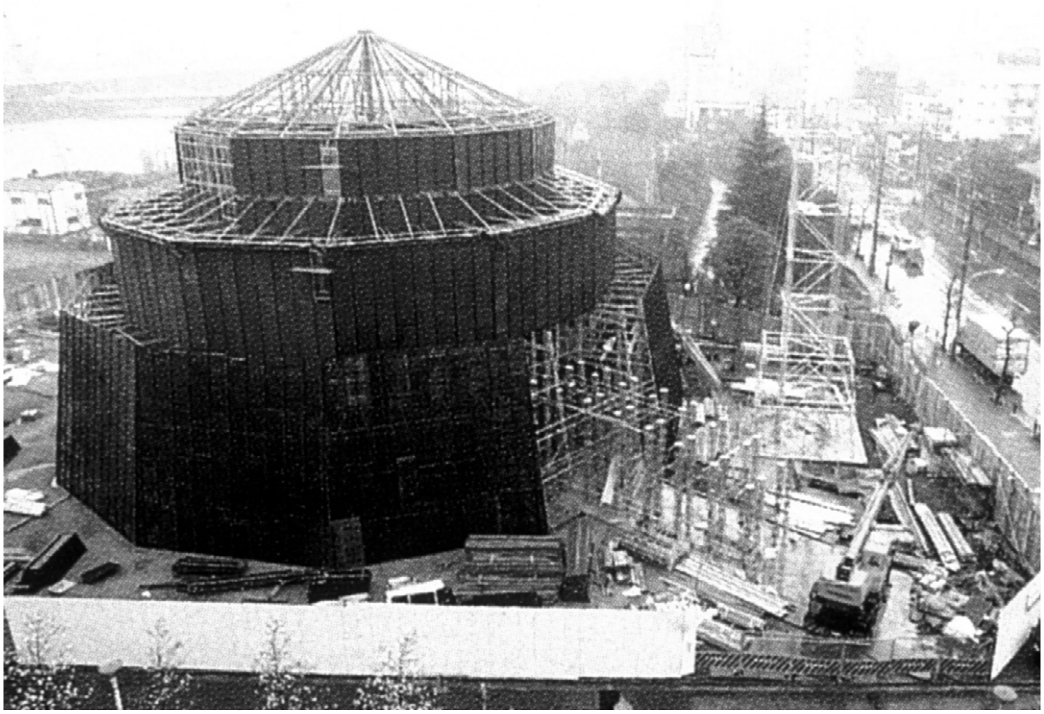

Fig. 2.7 Wall and roof structure complete and cladding underway. The entrance bridge in the foreground is under construction.

covers this space are also part of the transported component package. The constructional procedure consists of laying out the geometry of the building on the ground then erecting the scaffolding with the use of two mobile cranes (see Fig. 2.4). One mobile crane is located in the centre of the space and the building form is built around it with a small gap to allow it to leave when the building reaches full height. The timber cladding, stairs and roof membrane are added after the scaffolding structure is complete. Erection takes 15 days (Figs 2.5–2.7). The building was first built in the Northern Honshu city of Sendai in 1987 and then in Taito, Tokyo in 1988. Plans to erect the building at the Japan Festival in New York in 1989 did not materialise.

The Karaza Theatre was the first of three significant temporary buildings that Ando was to design within the space of five years, though it was the only one that was intended to be easily movable and has subsequently been erected at different locations. In 1990, the practice designed and built a temporary theatre for the projection of photographer Bishin Jumonji's work within an existing exhibition hall. This structure was built primarily from dark-stained scaffolding planks that contrasted with white canvas membranes and contained a thirty-seat open top auditorium.

Tadao Ando also designed the Japanese pavilion at Expo '92 in Seville, Spain which was one of the most imposing buildings on the entire site. The form of the building was obviously modern yet derived its inspiration from traditional Japanese architectural forms and conformed to the Japanese design philosophy based on kinari, unadorned beauty. The building structure was based on a series of grand timber columns that culminated in a constructed capital similar to that found in ancient temples though on a larger scale and built to a simpler pattern. The building was clad in horizontal hardwood boarding fixed to a light steel frame. The timber was visible both inside and out and though solid, complemented the translucent membrane roof because of its relatively lightweight nature in the structure of such a large building. The building had an impressive, even monolithic form yet it was constructed in a modular manner that reflected the traditional buildings of the past. Through its construction, it expressed a strong visual association with Japan's traditions, though these were merged with twentieth-century systems such as escalators (though entry could also be made via a *taikobashi* as in the Karaza Theatre) and a lightweight steel structure. The message which its form conveyed was of a present-day object based on a valued history.

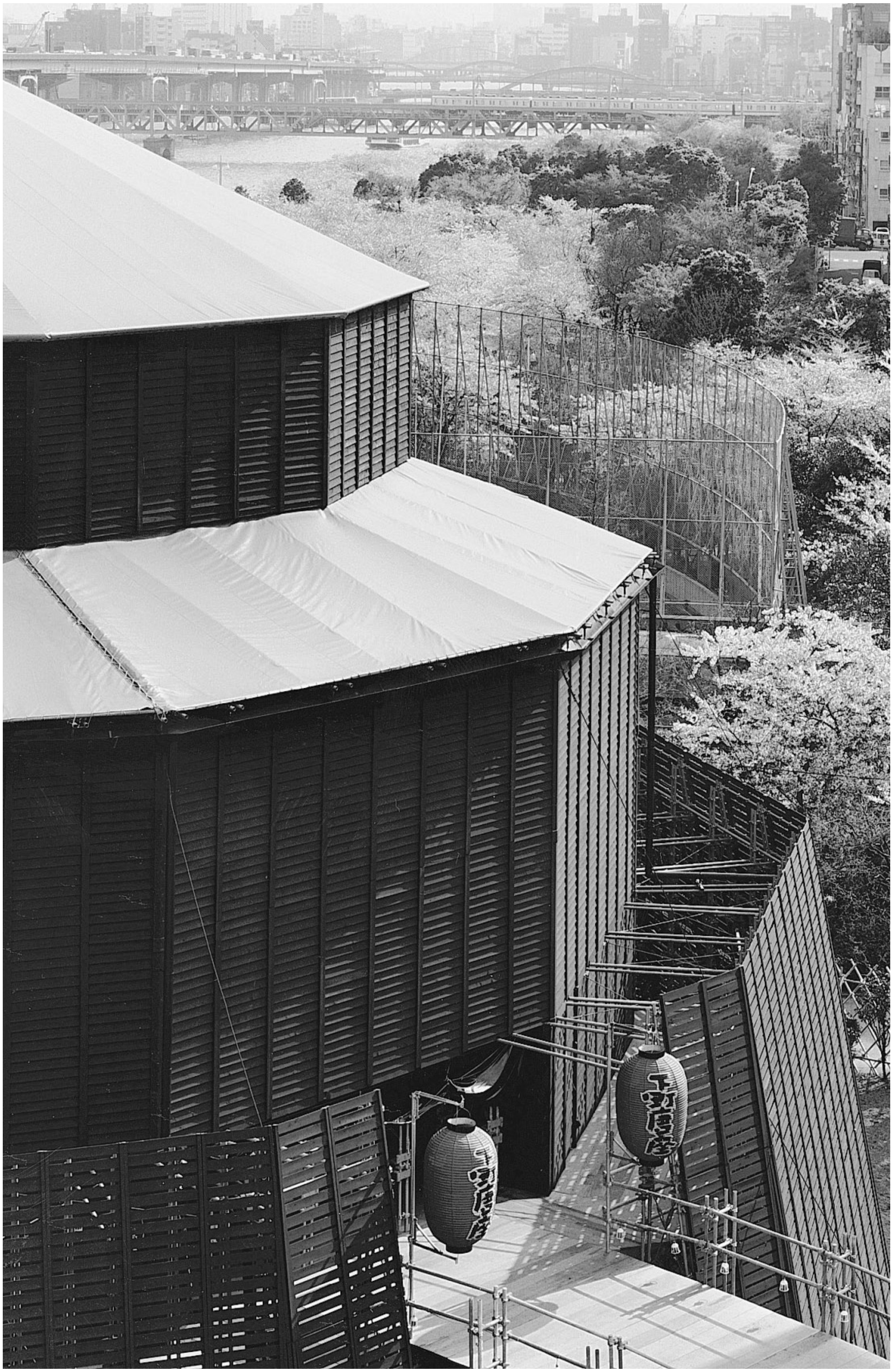

Fig. 2.8 Completed building showing the tension membrane roof and boarded cladding.

Fig. 2.9 Interior. Carpet covered bleacher-type seating. The dark fabric covered panels conceal access gangways and production equipment.

Both the Karaza Theatre and the Japanese Pavilion at Expo '92 used traditional ideas synthesised into contemporary form. The fact that these buildings accommodated modern functions and used contemporary construction systems expresses both the skill of the designer and the continuing relevance of the ideas that were adopted. One of the reasons that Ando has been able to approach the design of temporary buildings and, in the case of the Karaza Theatre, a mobile building with such confidence is that the tradition from which he derives his inspiration is not alien to transience. Though building materials and construction methods may have dramatically changed from those used in the past, they can in many cases still be described as adaptations of concepts familiar in traditional Japanese architecture. The Karaza Theatre and the Japanese Pavilion at Expo '92 utilised contemporary architectural principles and technology but because their use was harmonised with familiar cultural and social concepts (at least to members of the society which they served) they may be seen as landmarks in the continuum of ideas that establish the basis of architectural form in general. That these traditional concepts have found new relevance for contemporary functions proves that the transference of spiritual ideas about architecture can be expressed in new building techniques. The practical benefits of using more advanced constructional methods and new logistical approaches in the provision of buildings are more easily accepted as a beneficial innovation when associated with a continuing social and spiritual understanding.

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Museum of the Moving Image Hospitality Pavilion, London

Date: **1992–1994**
Client: **National Film Theatre/ Museum of the Moving Image**
Architects: **Future Systems:** Jan Kaplicky, Amanda Levete, Mark Newton
Engineers: **Ove Arup and Partners:** Peter Rice, Brian Forster, Alistair Lenczner
Consultants: Services: **Ove Arup and Partners:** Mike Beaven, Andy Sedgwick
Contractor: Fabricators: **Koit High-Tex** Steelwork: **Littlehampton Welding**

The application of innovative technology in building design is relatively rare, perhaps because clients' and contractors' perceptions of the risks involved are high. Even if architects and engineers are aware of the possibilities that innovation affords, cost and time constraints frequently mitigate against experimentation in construction practice. Very few architectural firms have therefore made consistent efforts to introduce new technology to live projects and thereby test experimental architectural concepts. However, without such projects the possibilities provided by the use of new materials and techniques may never be realised.

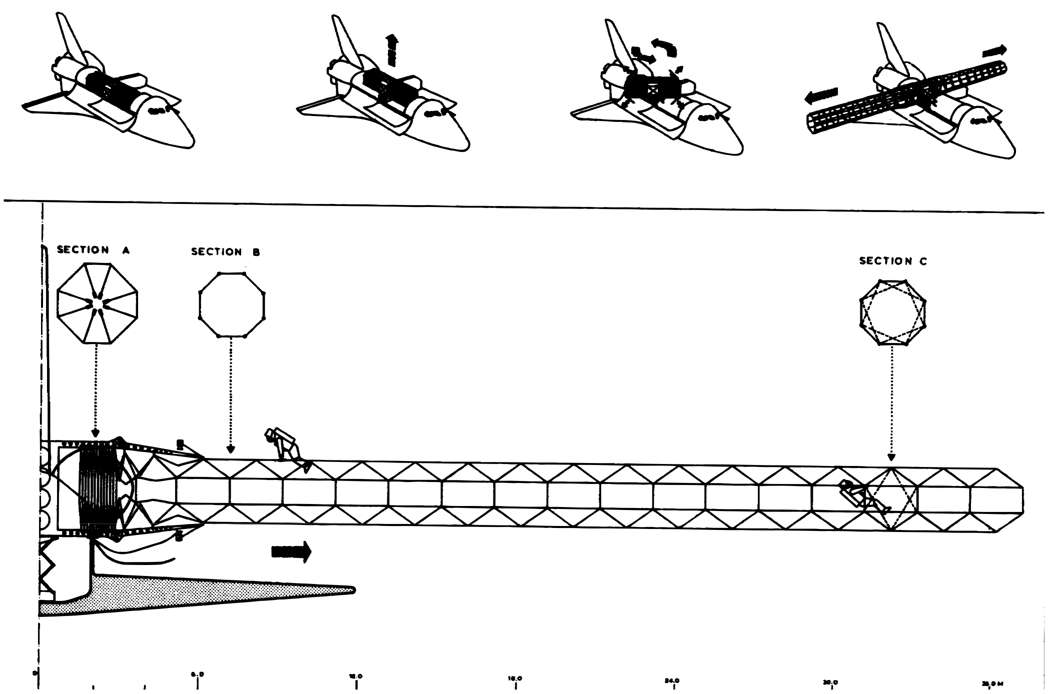

Fig. 3.1
Future Systems, Project 131, octagonal space beam system, 1985. A deployable octagonal structural beam system for use in space designed in conjunction with McDonnell Douglas Astronautics.

In many other fields of design, innovation is recognised as essential in order to increase standards and maintain competitiveness. In particular, transport design relies on such performance criteria to evaluate its success. To create vehicles that transport people and goods in the fastest, safest and most convenient way is often as important a criteria in this design field as economy. This has meant that research and development objectives are more closely identified with increased performance and the maximisation of efficiency rather than the minimisation of cost. In all fields of contemporary transportation technology, structures and materials play an important role in determining operational characteristics – lightweight structures, which are usually required to be of high strength, are generally the most efficient. The utilisation of spin-off technology from more advanced industries and transfer technology from other related fields is commonplace and an accepted valuable resource in the development of new strategies.

Future Systems was established in 1979 by architects Jan Kaplicky and David Nixon with the professed aim of exploring new directions in architecture by making use of available innovative technologies. Their ambition was not to use untried discoveries but to make use of techniques and materials that had already been tried and tested in the industry in which they had been developed, but had not yet been exploited in the building industry. Though Kaplicky came from Prague and Nixon from Bradford they met in London where they worked for the most technologically aware architectural practices of the 1970s such as Foster Associates and Richard Rogers.

For many years Kaplicky had experimented with a range of 'domestic' buildings that communicated a radical image derived from aviation and aerospace. Movability and flexibility of location was a vital factor in the design of these buildings which had increased potency by the suggestion that they may be placed in remote, often wild and beautiful, locations. This contemporary version of the rural idyll accentuated the power that technology possessed to place man in extreme environments with safety, comfort and minimal external effect on the surroundings.

In 1980, Nixon moved to Los Angeles where he became aware of the US Small Business Innovation Program which was encouraging design teams to seek funding for concept development work associated with space exploration. The aerospace programmes then being evaluated by NASA were based on the ambition to place a permanent space station in orbit by 1994 and a base on the Moon by 2005. Nixon and Kaplicky's interest in transfer technology led them to design several space exploration projects during this period. In 1983 they created a remotely deployable space platform that was to be pre-manufactured on earth, transported in the hold of the Space Shuttle and then erected in space. The lightweight graphite/epoxy frame could then be used as an orbiting platform for space station development and as a base for scientific and industrial operations. An automatically deployed space beam system was also developed in 1985 in conjunction with McDonnell Douglas Astronautics (see Fig. 3.1).

The practice also developed concepts associated with habitation modules in space including a flexible crew base for a modular space station and specialist component design such as an adaptable crew table that could accommodate the specific problems of weightless conditions and be used for work, meeting and meal times. Design work was also carried out on structural systems that could be used on the Moon to support lunar regolith (the equivalent of terrestrial earth) to act as a shield for habitation modules. These structures consisted of ultra-lightweight graphite/epoxy composite beams and struts that would support a fine woven graphite fibre mesh upon which the mass regolith shield would rest.

Though on first examination these designs might appear to have little in common with conventional architectural work the design briefs were in fact wholly concerned with finding workable solutions to practical logistical constructional problems. Significantly in terms of portable building design, these projects utilised materials and techniques with much higher performance characteristics than those habitually used in the building industry and for Nixon and Kaplicky they undoubtedly reinforced the possibilities that technology transfer possesses for architectural design. The fact that these projects also deal with building at remote sites in difficult conditions is also valuable in terms of similar, if less extreme, terrestrial design problems. Spin-offs from the aerospace exploration industry are numerous and wide ranging in the effects that they have had; however, in the building industry they are relatively few and peripheral in their impact. Though flat cable systems and pholtaic-solar panels originally designed for use in spacecraft and satellites have found terrestrial applications, fundamental structural techniques and new materials developed for use in space exploration remain relatively unexplored.

Future Systems' work has delved into the possibilities that these systems offer and the practice has created a continuous stream of exciting projects that

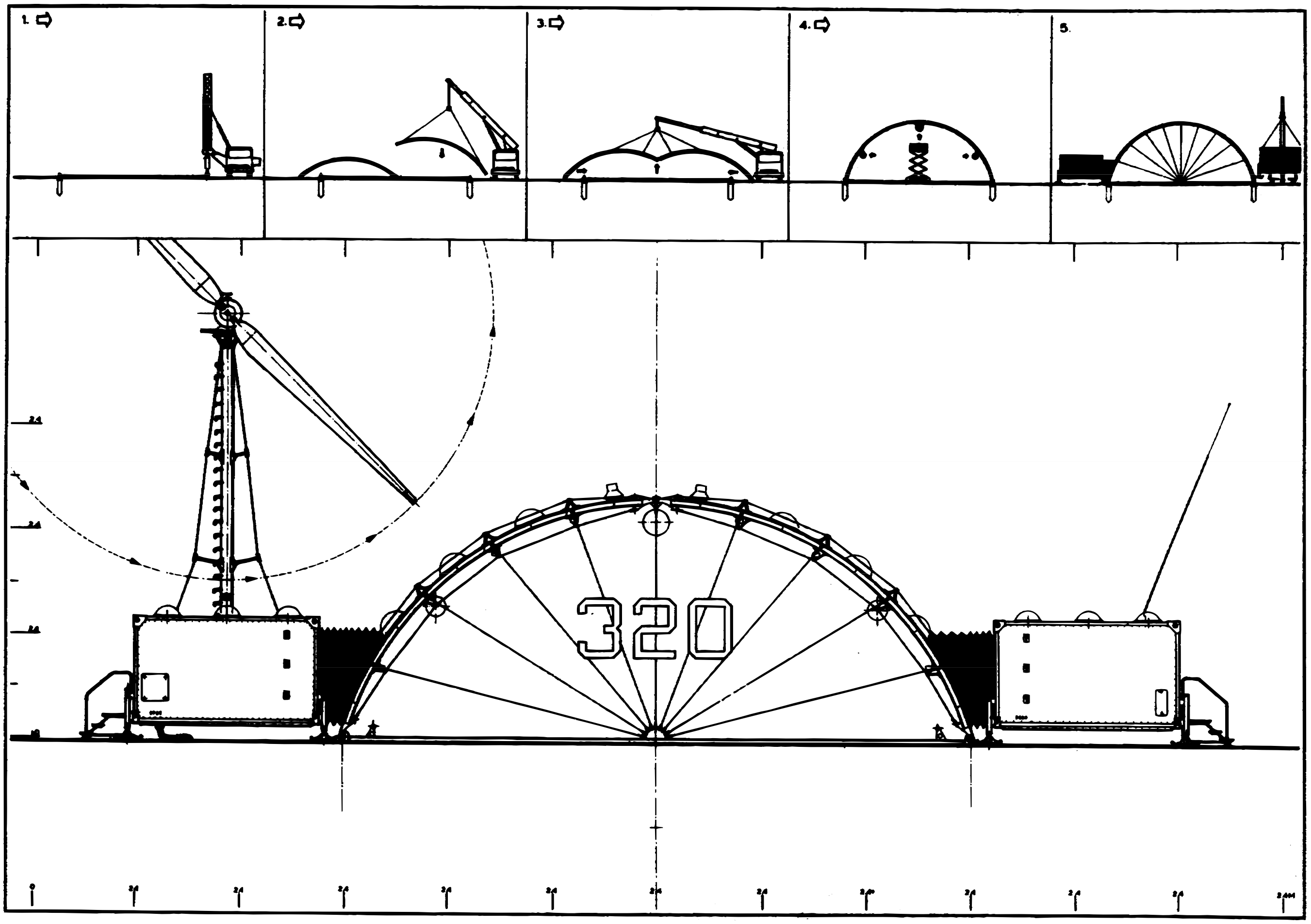

Fig. 3.2 Future Systems, Project 115, prefabricated industrial nursery, 1983. A modular prefabricated building system designed for adaptability and flexibility.

have been enormously influential on a whole generation of designers. Despite many very close run competition entries that have almost resulted in a major commission, until recently, significant built work has been rare. In 1989 Amanda Levete joined the practice and the fruitful long-term partnership between Kaplicky and Nixon was gradually set aside to begin a new era during which the ambition to build became even more important.

The Museum of the Moving Image Hospitality Pavilion (MoMI)

After the dramatic, widely publicised projects that Future Systems designed in the late 1980s and early 1990s it is perhaps surprising that their first high-profile built commission was for a relatively modest temporary 'tent', yet this small structure is nevertheless of importance in that it incorporated many of the issues dealt with in their earlier work and exhibited an exciting image that was all the more potent for its realisation in built form. An earlier project designed by Nixon and Kaplicky in 1983 indicated some of the ideas about practical movable buildings that had been in place for many years. Project 115 was a speculative design for a prototype industrial building that utilised many prefabricated and temporary building features and exhibited a similar form to the MoMI tent (see Fig. 3.2). The project was the fourth in a series of studies that investigated the provision of adaptable accommodation for industrial use. The building utilised a whole series of prefabricated components that could be easily transported to site and erected with minimum effort to provide a sophisticated industrial building. The design avoided the delay of conventional building operations and services connections and though particularly suited to remote locations, was also intended for use on conventional sites for businesses that required accommodation quickly. The floor slab was to use a proprietary aircraft runway system that consisted of interlocking aluminium decks, and the main building consisted of a semicircular shelter composed of prefabricated steel panels. These were to be connected together on the ground then lifted at the centre position by the same crane used for component off-loading. The perimeter edges of this three-pin arch were to be fixed into the ground using helical screwed anchors and further reinforced by external tension cables. The end panels of this unlimited length building could utilise a variety of configurations including large doorways for deliveries and the entry of vehicles. Modular volumetric containers were to provide more complex facilities such as servicing equipment and staff accommodation including a wind generator as an additional power source in suitable situations. Though quite different in detail and function, the form of this structure and the principles of prefabrication and easy assembly, mirror the ambitions of the later MoMI project.

The hospitality pavilion was created in response to a brief set by the National Film Theatre and the Museum of the Moving Image which required a temporary tent that could be used for a wide range of functions associated with their permanent buildings situated in London's South Bank cultural area. Though many of the city's most important arts buildings are situated on this embankment that fronts onto the River Thames, the site is a relatively inhospitable continuous concrete flagged surface which is elevated away from the river and broken up by high level bridge approaches. The spectacular view across the Thames is compromised by the inadequacies of the local environment. Any addition to this site, even of this temporary nature, could clearly have an important task in defining the future development of the area.

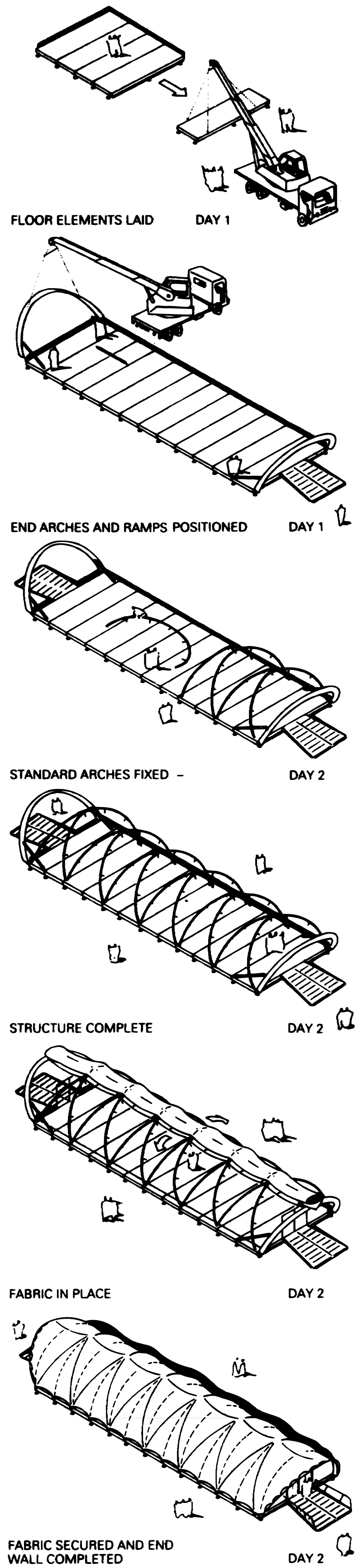

Fig. 3.3 Future Systems. Museum of the Moving Image hospitality pavilion, 1992. Erection process.

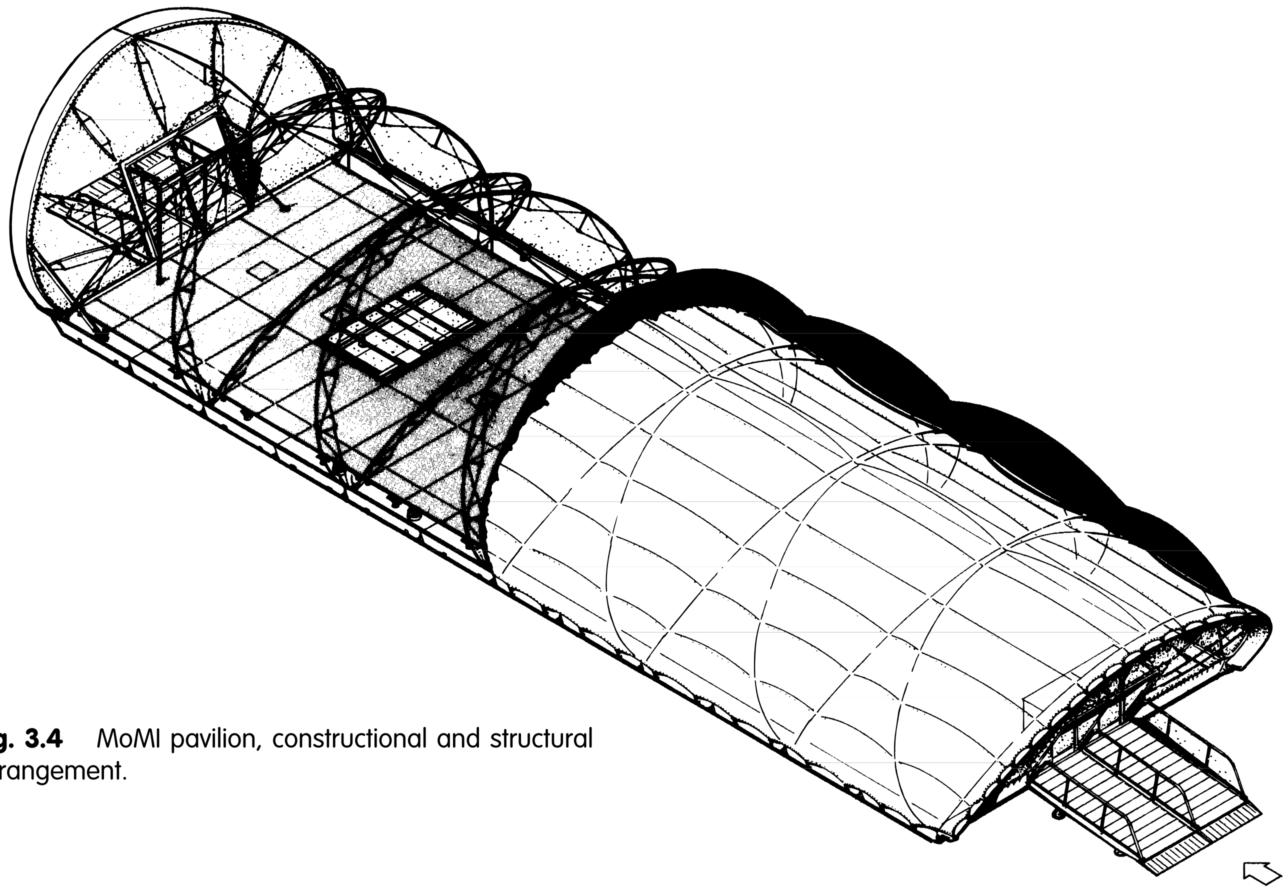

Fig. 3.4 MoMI pavilion, constructional and structural arrangement.

The building was designed to accommodate up to 450 people for periodic receptions associated with film festivals and other special events and was required to be capable of being erected and dismantled quickly and stored in a minimal space when not in use. Clearly, as an event structure the building had to have a dynamic image that would announce its presence to the public both at night and during the day. The designers' solution was to create a 28.8 metre by 9.6 metre fully serviced building that could provide all the facilities of a permanent space and utilise its ephemeral nature to create a charismatic image (Fig. 3.4). The basic form is a semi-elliptical tube of translucent material with transparent gables at each end. The arches that support the skin are made from polytrusions, glass-fibre reinforced polyester rods fixed with epoxy to stainless steel joints braced with stainless steel cables. The arches are positioned in a rhythmic inclined pattern that is continuous throughout the length of the building. Two arches spring from each point at the edge of the floor and separate as they rise to join at the apex with arches that spring from the adjacent bay. This continuous form not only reduces the need for lateral positioning and bracing during erection but adds to the dynamic quality of the structure once erected. By creating an internal structure that operates without a linear member, the emphasis on the fabric skin (which is the lightest part of the structure) is therefore enhanced, as is the overall lightweight nature of the building.

The main fabric membrane was made from polytetrafluoroethylene (PTFE), Tenara woven fibre, patterned and seamed in Germany. This was connected to the arches, which were highly curved to provide extra strength, to form a semi-monocoque system that would be at its strongest when the skin was fully tensioned. This material, though less strong than more common fabrics used in building structures, was chosen for its greater flexibility and suitability to the erection and dismantling process as well as for being up to four times more translucent than other membrane materials. The end walls used Hostaflon ETFE, a transparent film which also required a curved structure to provide rigidity (Fig. 3.5).

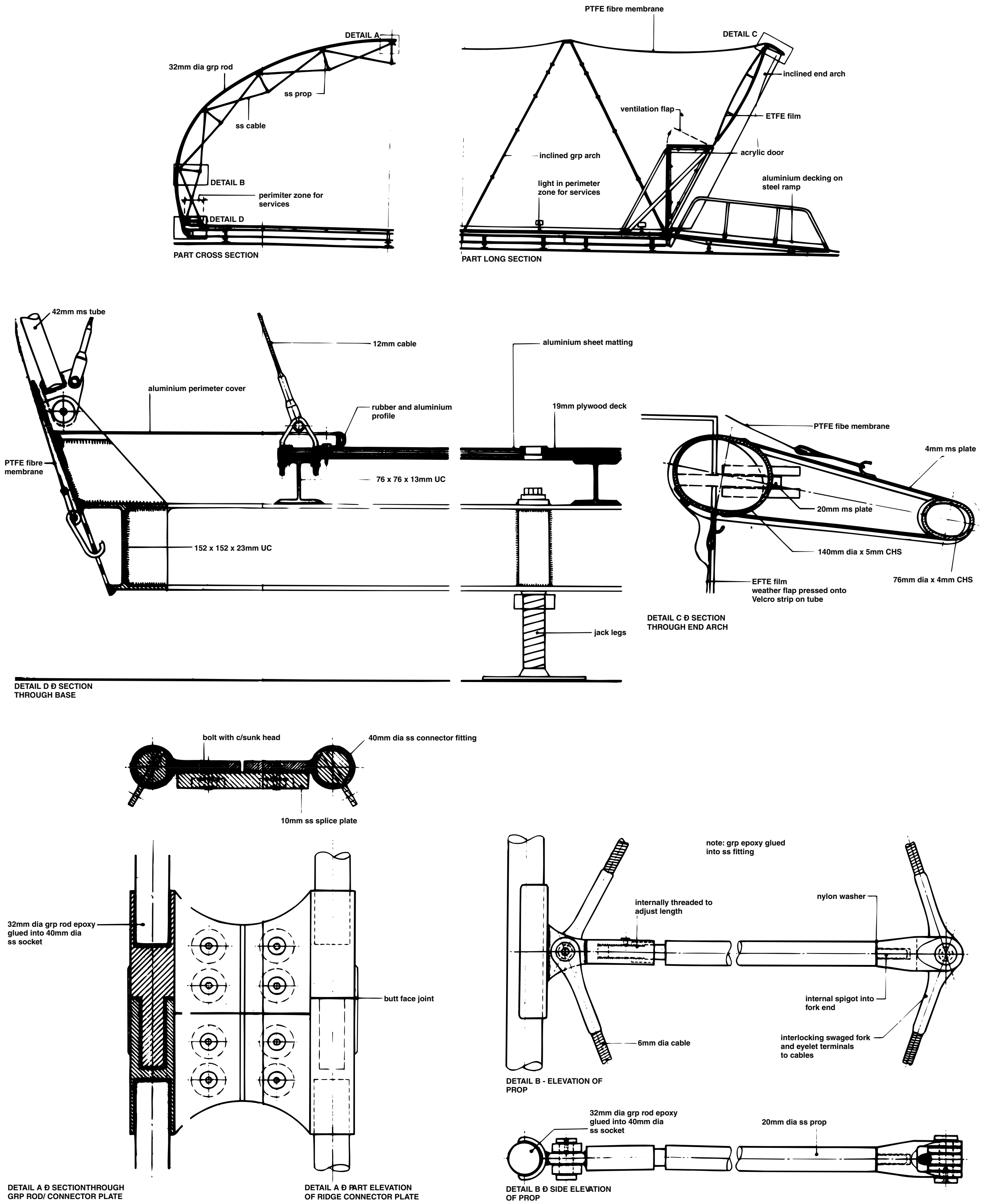

Fig. 3.5 MoMI pavilion. Top: part cross-section and part long-section, centre: section through base and end arch, bottom: GRP rod structure details.

The building can be erected by six people in two days and dismantled in less. Manufacture was undertaken by building contractors accustomed to the normal operations of the building industry and used a standard JCT 80 contract. The fabricators, Koit High-Tex, were also contracted to assemble and maintain the structure. The deployment procedure follows a preset pattern (Figs 3.3, 3.6–3.7). First the 9.6 metre by 2.4 metre steel floor panels are placed in position on their adjustable jack legs with a fork-lift truck. The floor finish uses a plywood deck with an aluminium sheet covering. The end arches are substantial steel frames made from hollow steel sections and plate and are lifted in by

Fig. 3.6 Erection of the end arch section.

Fig. 3.7 The bare structure before cladding with the PTFE membrane.

Fig. 3.8 MoM pavilion, view towards the entrance. The structure makes a striking contrast with the heavy concrete bridge above.

crane and fixed to the floor structure with diagonal struts that brace them in position. These arches lean outwards to resist the linear tension of the membrane skin. The main lightweight arches are then assembled on the ground and lifted into place and fixed at the base. Once the primary structure is complete the fabric membrane is spread over it and tensioned down to edge connections along its length and at the end arches. Entry and exit is by a pair of transparent, acrylic double doors situated in each gable end. These are placed in a steel frame that also supports one end of the gable membrane braces, which connect at the other end to the steel arch. The gable membrane is fixed to the door frame and the arch, and incorporates a weather flap that is fixed by Velcro.

A raised aluminium cover plate at floor level is positioned down both sides of the building and the uplighting and air supply and extract fans are located in this area. Adjustable flaps in the cheeks of the door supports allow cross-ventilation, and electrical and other supplies are concealed beneath the raised floor. The entire structure fits into three lorries and the fabric into a one metre cube.

When in position on the South Bank this building appeared to exemplify lightness, balance and efficiency both by day and night. Its situation was beneath a concrete road bridge and its juxtaposition with this heavy structure accentuated its dynamic qualities (see Plate 4). At night, the light from within illuminated the pattern of the structure and emphasised the building's simple graceful

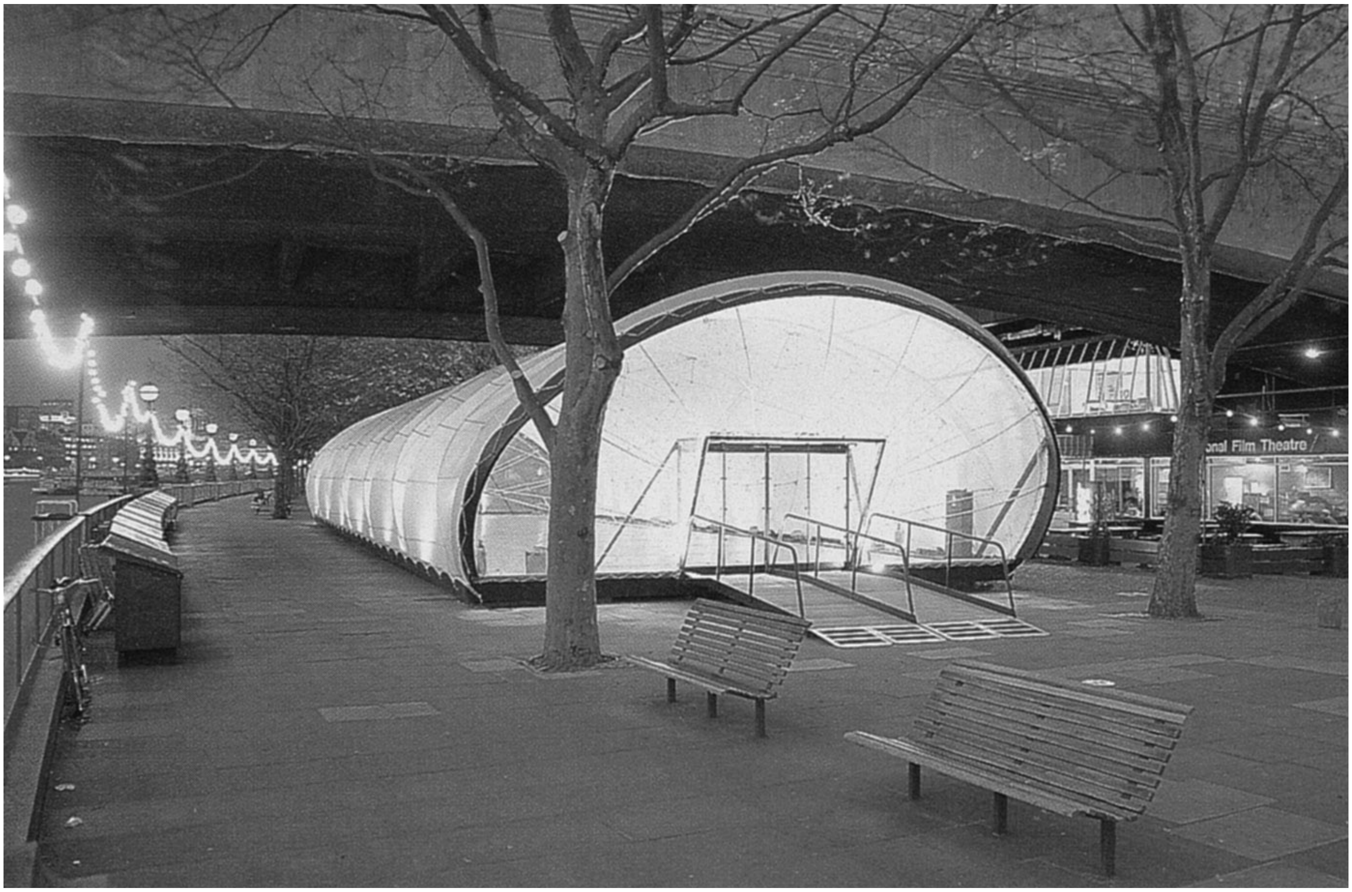

Fig. 3.8 At night the building conveyed a translucent floating presence.

shape. From a distance it appeared to hover above the edge of the river and as the visitor came closer its characteristic warm, glowing light became a counterpoint to the darker mass of the surrounding buildings (Fig. 3.8).

Future Systems collaborated with Ove Arup on the building's structural specification and this project was one of the last to be worked on by the talented engineer Peter Rice before he died. Rice's sensitive understanding of the nature of materials is manifest in the structural strategy which helps to accentuate the qualities of the architectural form. Future System's commitment to the use of transfer technology is also exemplified in this building's construction. For example, though the use of the GRP rods in the arches is an innovation, this is a material with clearly understood and well-tested capabilities in other applications. In general the materials have been chosen with care, not only to achieve the logistical objectives of demountability but also to express the constructional functions that they serve. The relationship between different materials and components has been carefully manipulated to accentuate their distinctive roles. The main arches are slender and light and have been purposefully braced by the membrane rather than additional linear members. The end arches are relatively heavy to indicate the transference of the force of the membrane along the length of the building down into the floor structure, but they are also painted black to act as a foil to the other light-coloured and lightweight structural elements. The transparent skin at either end of the building accentuates the linear route of the South Bank walkway but also the infinite theoretically extendible form of the building.

The entire South Bank site is now to be redesigned to enliven and enhance the nature of its use and mitigate the poor environmental conditions which are inappropriate for one of the most important cultural sites in London. Temporary buildings have the ability to form a catalyst in such sensitive prominent locations and may indicate new possibilities where none was thought to exist before. The fact that for at least a short amount of time a portion of this site became welcoming, exciting and eminently usable is a clear indication that a long-term solution can be made to work, and a physical reinforcement of the value it would have.

The main structure for the MoMI hospitality tent is still in storage. After being erected and dismantled three times on the South Bank site the building was used in another London location adjacent to high-rise buildings. On the night of 8 December 1994 storm force winds destroyed the main membrane and if the building is to be used again a new one must be manufactured. The fact that this building was damaged should not, however, be seen as a sign of its failure. It proved dramatically successful in the site for which it was designed and may have continued to be used in similar sites for years to come. Portable architecture, like all other forms of architecture, is designed to satisfy dedicated functions and budgets and its success should be rated against the design brief, not against its ability to withstand unspecified situations. An appropriate analogy from the motor industry would be that you would not expect a compact town car to withstand the rigours of unmade tracks in four-wheel drive, cross-country terrain. The MoMI pavilion utilised innovative materials and techniques that as well as supplying a beautiful and functional facility for the client, also enhanced our understanding of what modern architecture can be. The full potential of the principles it used have yet to be fully explored. It communicated, in an elegant and exciting way, the possibilities not only for temporary buildings in general but also the important effect that they can have on the permanent environments that they inhabit. Though buildings such as this may be intended to be ephemeral, their influence can have permanent results.

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'Airtecture' Air Hall

Date: **1996–1999**
Client: **Festo KG, Esslingen, Germany**
Architect: **Festo Corporate Design, Lead Designer:** Axel Thallemer
Engineer: **Festo Corporate Design**
Environmental Design: **Festo Corporate Design**
Contractors: Pneumatic systems: **Festo KG;** Membranes: **Continental Rubber Company, Hanover, Germany;** Erection: **KOIT, Riemsting, Upper Bavaria, Germany**
Cost: **DM2.4 million**

Airquarium, Germany

Date: **2000**
Client: **Festo AG & Co.**
Designer: **Festo Corporate Design, Lead Designer:** Axel Thallemer**, Membrane Engineering:** David Wakefield
Contractor: **Koch Membranen, Remsteng, Germany**

Totally experimental projects that have the purpose to pave the way for new forms of design are an accepted part of many industries' research and development strategy, particularly those where innovation is the key to maintaining the competitive edge – for example aerospace, motor racing or information technology. In architecture, the erection of full-scale buildings to perform this task are extremely rare – individual component manufacturers will prototype their own products, organisations such as the Building Research Establishment will construct mock-ups to test performance and safety, but the creation of an entirely new building in which all the elements are part of a new interrelated approach to building design, manufacture and erection is something that the building industry, composed as it is of a network of intertwined yet competitive organisations, apparently cannot bring itself to undertake. Occasionally, 'experimental' buildings have featured in specialist building exhibitions or as part of commercial expos, however, there is often a hidden agenda with such projects, the experimentation being a ruse to draw attention to their sponsor, rather than a serious attempt to explore the limits of a genuinely innovative concept. It is therefore not surprising that the experimental building examined here has been erected outside the conventions of the construction industry, by a multinational company whose main operations are not concerned with architecture at all.

'Airtecture' Air Hall

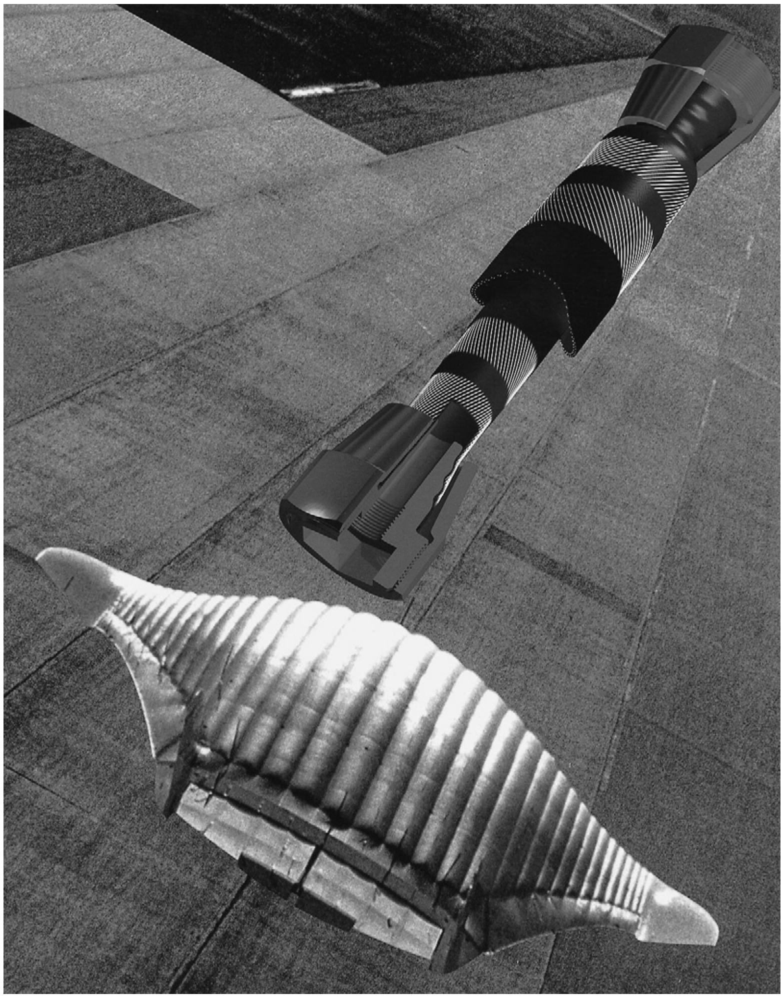

Fig. 4.1 Festo Corporate Design projects – the pneumatic muscle and the Stingray flying wing aircraft.

Festo is the world's leading innovator and manufacturer in the field of pneumatics and their products are used in virtually all industries where automation is a feature of the manufacturing process. The company designs and produces actuators, sensors, processors, and networks that operate and control the machines that make modern manufacturing possible. This is a high-tech business that encompasses every aspect of the world's industrial output, from motor manufacturing to milk production. Festo maintains a presence in more than 160 countries world-wide and has 52 subsidiary companies. It is perhaps surprising then that it is only recently, 69 years after the company was founded, that Festo set up a corporate design department to analyse its goals and objectives and to create a unified, recognisable image built around their existing achievements but also around a vision of the future in which innovation is the key to success and further development.

Axel Thallemer was appointed to set up and head Festo Corporate Design in 1994. Trained as an architect, Thallemer moved into design engineering in his personal search to play an active role in the creation of truly innovative products. Previously he had worked at Porsche's research and development centre, involved in the development of Group C/Formula 1 racing cars and the Porsche Boxter/911 Carrera sports car. In creating a new image for the Festo company the Corporate Design department has developed a range of innovative cutting edge prototype products that not only break new ground in terms of technology and performance but also play an important part in developing the public image of the company. The department's ambition is to première at least one new design prototype each year and though all are based around the company's core expertise of pneumatics, the range of applications is wide. In 1994 a pair of hot-air balloons began a tour of the world, unique in that though they were identical in appearance, one flew in an apparent 'upside-down' configuration. In 1995 the 'Y'-shaped column that would form the basis for further work in 'Airtecture' was premièred, and in 1996 the completed exhibition hall made its first appearance. In 1997 they constructed the first inflatable hot-air balloon basket, in 1998 the first inflatable gas balloon basket. In 1998 they also announced the creation of a pneumatic muscle, which is a new type of hyper-efficient pump that uses no moving parts and is therefore remarkably economic and reliable in use. 1999's product is an inflatable flying wing aircraft that replaces conventional rigid aerofoil surfaces with a completely pneumatic structure (Fig. 4.1). The philosophy behind these products can best be described by Festo's motto 'Air in Air', which encapsulates the idea that the air itself can be a powerful active force in the generation and operation of machines and structure.

The term 'Airtecture' does not refer to a single building but the philosophy of making conven-

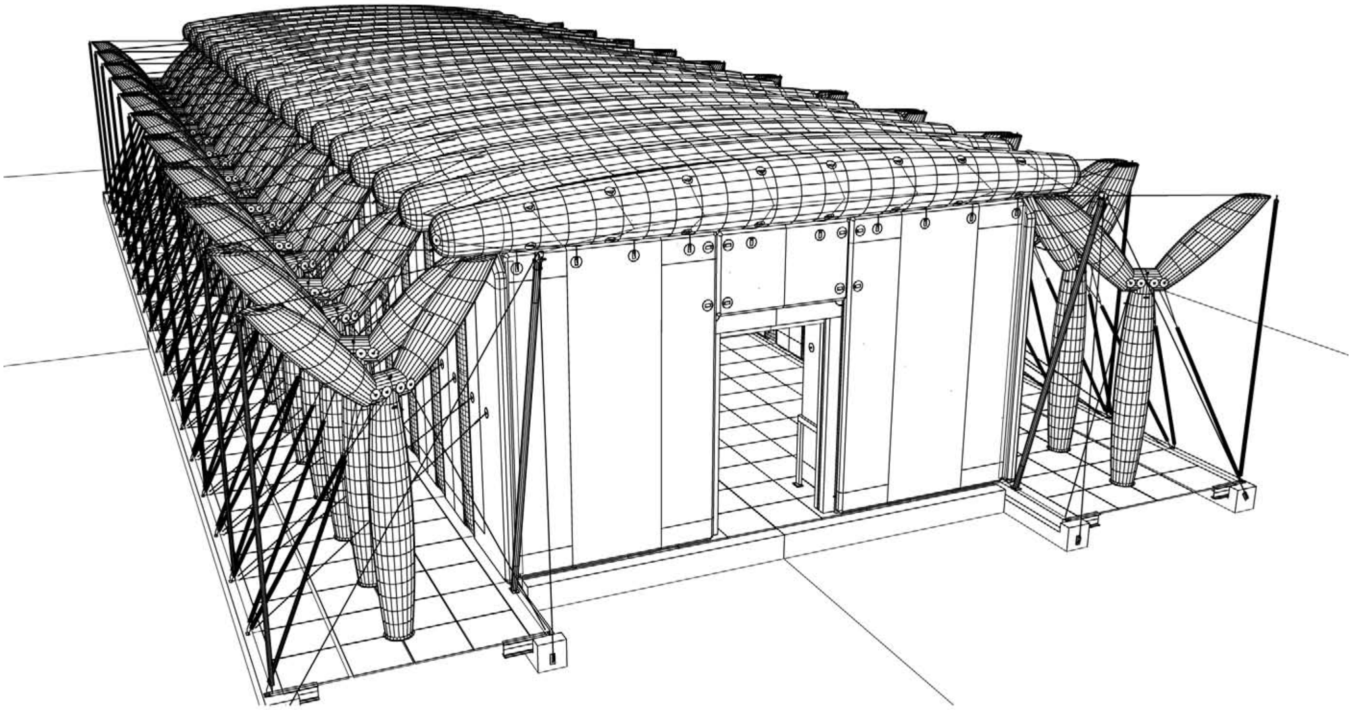

Fig. 4.2 'Airtecture' Air Hall, computer-generated perspective.

tional building elements, such as columns, walls, roofs or windows, from membranes prestressed with air. It is possible for such buildings to have an interactive relationship with their environment. With the use of sensors, actuators, and computers they can actively respond to input from weather-monitoring equipment which measures external wind loads, snow loads and temperature changes, providing the data that instigates changes in the building's physical form and services operation. The use of air as a main constructional element makes the building lightweight, dynamic, and capable of achieving the highest levels of thermal insulation and energy efficiency. The 'Airtecture' exhibition hall is the first building to incorporate this comprehensive approach throughout its construction and operational systems. It has also been designed to be completely portable and can be packaged into a single standard ISO shipping container (Fig. 4.2).

Thallemer's idea for the 'Airtecture' hall stemmed from a number of areas, though he was conscious that in order to fulfil the ambitions of his company the final design should essentially be one without direct precedent. Bionics was an influence on the original concept, the form of the 'Y'-shaped column in particular, being derived from the shape of the wing of a dragonfly. Conventional inflatables were definitely not an influence as he believes that these are comparatively simple, passive structures whose form is only loosely determined by the structural system. The only building that has inspired him is the Fuji Pavilion designed by Yutaka Murata for Expo 70. This building consisted solely of interconnected high-pressure air beams formed into an organic tunnel-like shape over a circular plan. At the time it was built it stretched the current technology both in membrane design and in pneumatic control systems to the limit.

The 'Airtecture' hall encloses a rectangular 375 square metre internal space that is 6 metres high. This volume has the flat walls and flat ceilings of conventional building forms and therefore, is quite different from most tensile membrane buildings which must usually consist of the double curved surfaces that generally form the strongest pneumatic structural systems (Figs 4.3–4.4).

The outside of the hall is quite different to the interior and can best be described as an exoskeleton. This supporting structure consists of forty, 6 metre high 'Y'-shaped columns, linked together by 12.7 metre long horizontal air beams and braced by vertical and diagonal pneumatic muscles (Figs 4.5–4.6). The columns and air beams are made of a conventional synthetic fabric, polyamide, and coated with a Hypalon flame-inhibiting elastomer coating.

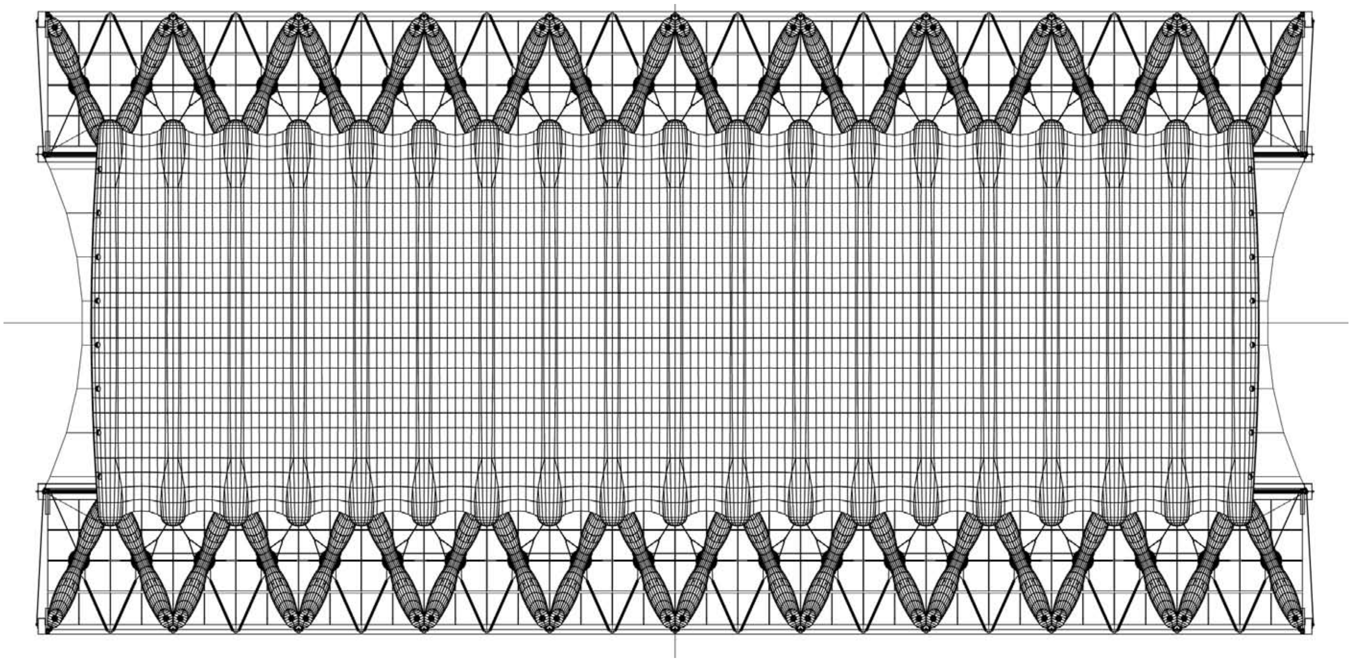

Fig. 4.3 Roof plan.

The air beams range in diameter from 0.75 metre at the ends to 1.25 metres at mid-span and are fixed with stainless steel connectors to the walls and column points and located laterally over their span by textile belts (Fig. 4.7). Stainless steel cables and struts are also used where remote element-to-element connections are required. When viewed in plan the top points of the'Y'-shaped columns rotate back and forth to triangulate the structure. The building's longitudinal stability is aided by two sets of diagonal pneumatic muscles at either end of the building. These are also used at every column bay to stabilise the building across its width. The muscles are made of polyamide fabric with an internal silicone hose. Unlike conventional tensile cable which is tensioned only once when a building is completed, this element is constantly regulated by varying the internal air pressure between 0.3 and 1 bar, providing a wide variation in axial force. The air beams can be pretensioned in the same way to resist variable wind and snow loads.

The hall walls consist of specially developed, double-skin, air-tensioned polyamide membrane 'slabs' (Fig. 4.8). These wall units are 200 mm thick,

Fig. 4.4 End elevation.

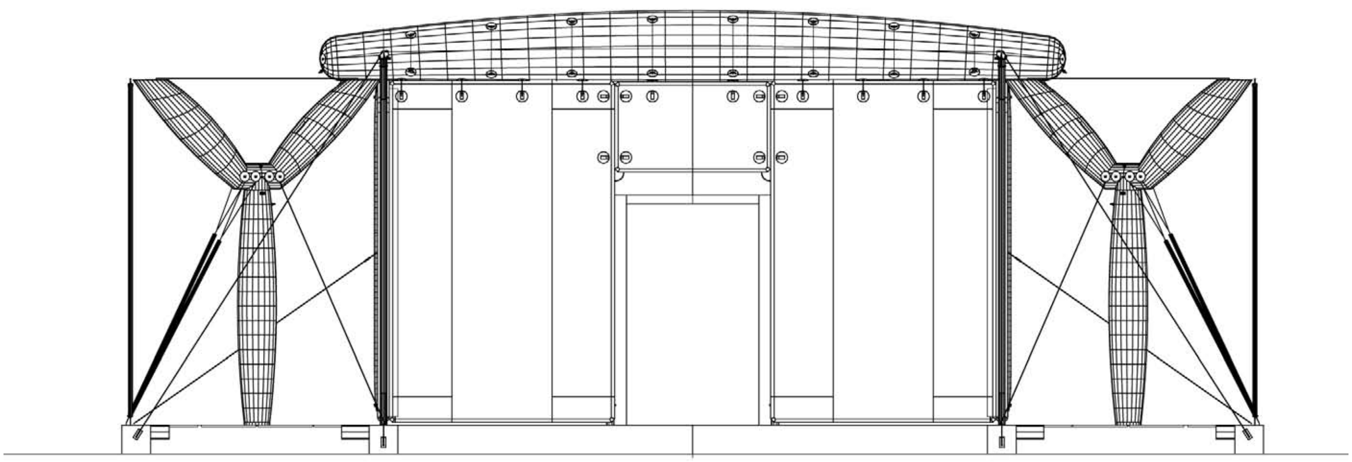

Fig. 4.5 Side view showing the 'Y' columns, cable bracing and pneumatic muscles.

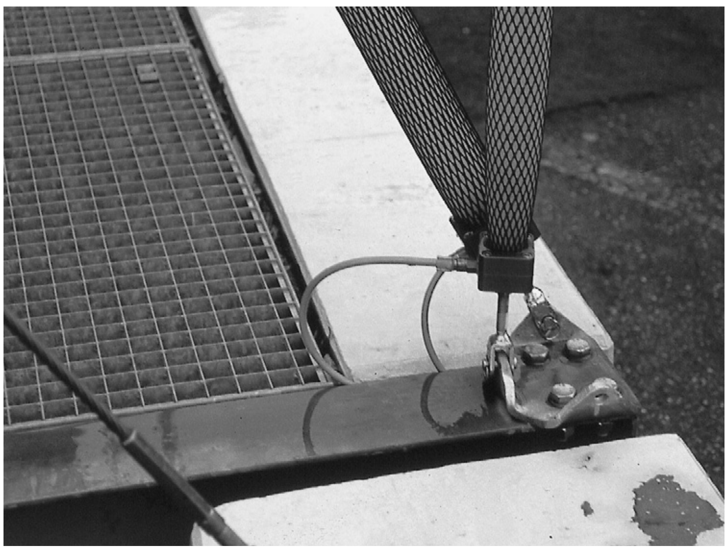

Fig. 4.6 Pneumatic muscle connections to base framework.

the two surface membranes continuously coupled by 72,000 threads per square metre and tensioned by air pressure at 0.5 bar. This system has been developed from carpet weaving tufting technology and was derived to satisfy the desire to make a flat element comparable with conventional building wall conditions from tensile membrane components which normally require curved surfaces to attain their rigidity and stability. Natural light is admitted though Velaglas membrane envelopes, a new chemically altered natural rubber that takes the form of a transparent elastomer. In the roof these envelopes maintain rigidity through a partial vacuum. The structural stability of the roof is therefore achieved by alternating structural elements using positive and negative air pressure (Fig. 4.9). These 'window' areas also provide the tolerance for movement throughout the entire structure.

The building consists of more than 330 individual air-supported elements with varying air pressures and volumes. For control purposes these elements are grouped into ten identical sections. The air pressure levels are controlled by proportional valves and the real-time pressure within the elements is monitored by sensors. Pressure-relief valves automatically release excess pressure should it be necessary. A single computer controls a subset of ten slave computers, varying the pressure in individual elements according to climatic conditions. The building was designed to resist a 180 kph wind speed combined with a simultaneous snow load of 80 kilograms per square metre. The highest wind yet experienced at the prototype site has been 220 kph and the building did not move at all, though the extra air pressure in the structural elements meant that it swelled by 600 mm overall. During this extreme wind the designers further tested the building's systems by instructing the computer to loosen one-third of all the pneumatic muscles, thereby simulating a wind load of 250 kph. The result was that the walls shivered! However, no damage was done.

This prototype 'Airtecture' hall was erected at the Festo company headquarters in Esslingen, near Stuttgart, Germany. The entire structure sits on a steel frame system that is situated 500 mm above ground level. Though it was designed as a portable building, in this

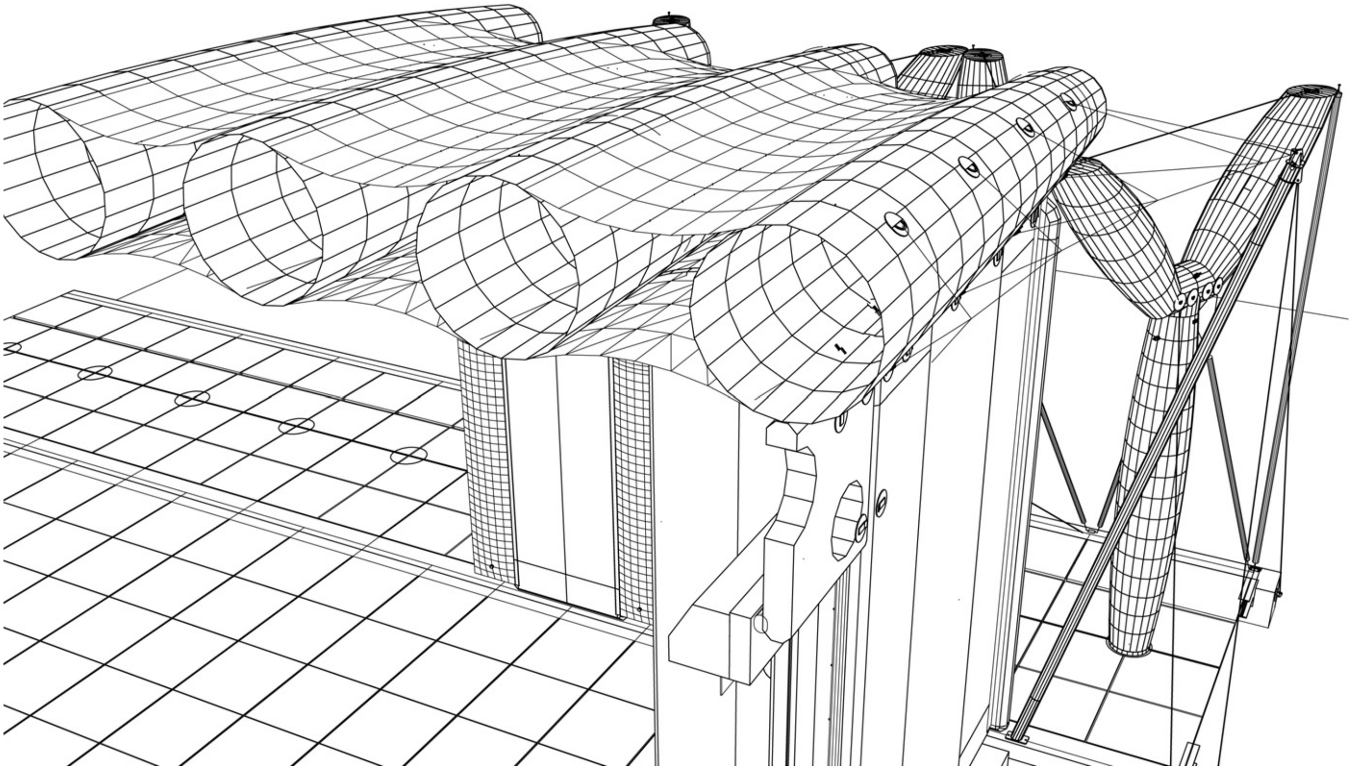

Fig. 4.7 Perspective section through air beams.

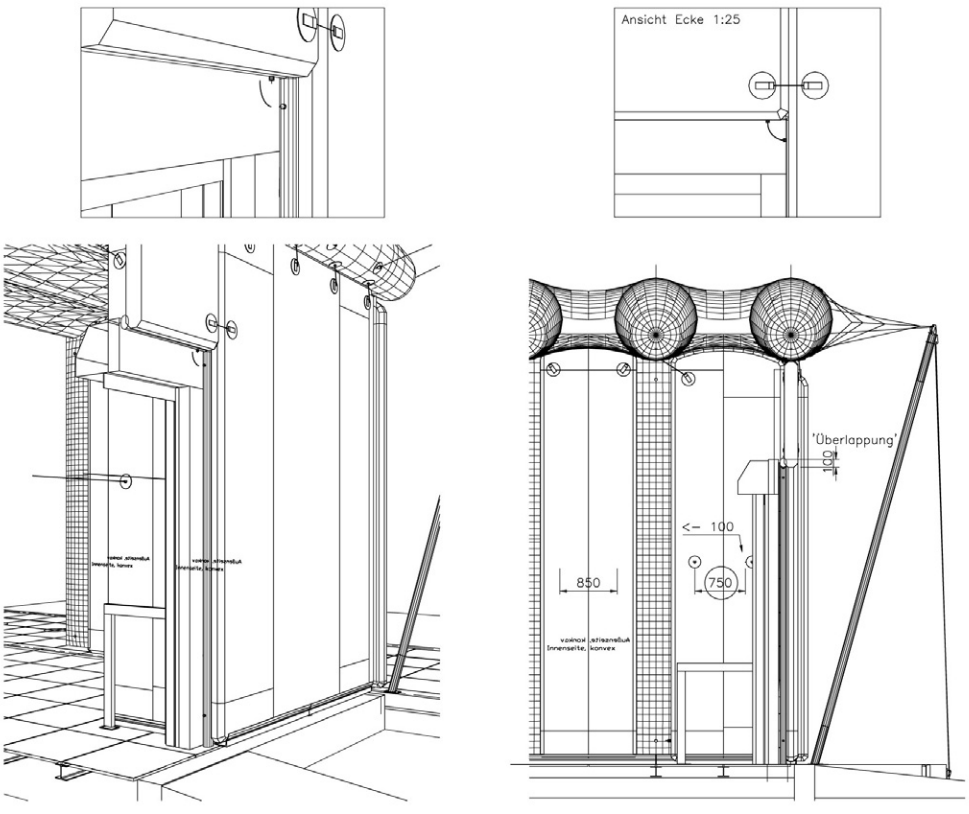

Fig. 4.8 Air-tensioned membrane slabs are fixed to each other in the end elevation (left), and to separating transparent membrane envelopes in the side elevation (right).

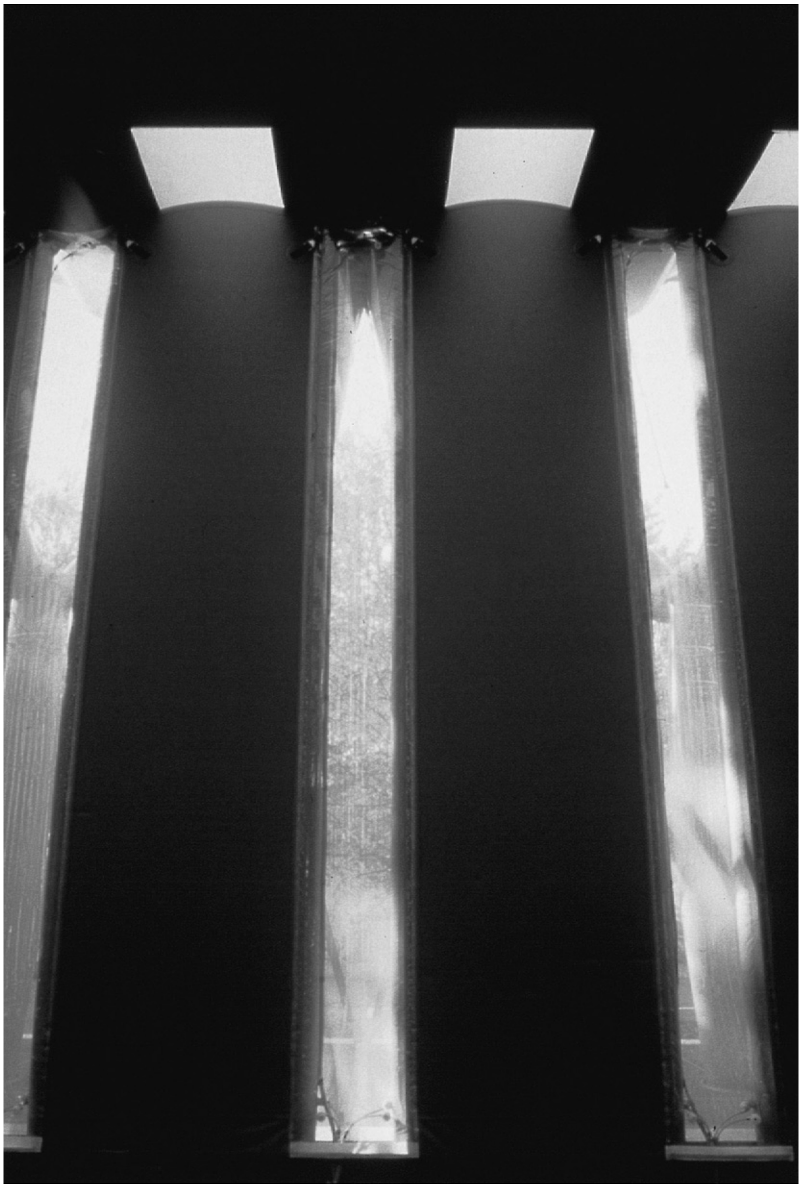

Fig. 4.9 Transparent and opaque envelopes alternate along the building's length.

case the steel frame has been erected on permanent foundations allowing the installation of a transparent metal grid floor that allows all the air pressure valve and controls systems that are so unique to be viewed in operation. The concept for the 'Airtecture' hall was approved by Festo KG in December 1994 and a prototype 'Y' column was completed by April 1995 and exhibited at the Hanover Fair Trades Exhibition. Four different column patterns and four different air beam designs were studied before building a prototype of one complete sectional bay – the current design was chosen because of its superior resistance to buckling. Because this was a new form of construction, communication between the prototype manufacturer and the designers had to be both instant and fluid. The building was designed completely on computer and the specifications and drawings communicated to the manufacturing contractors by the transmission of data files. The first air column fabric joints were made in conventional membrane construction manner with a lap joint, however, owing to the extreme air pressures demanded for this building, these failed because of excessive shear. A new pattern using butt joints with an extra layer on each side was adopted which proved successful. Once construction began, no further changes were made as the design had then been through an extensive computer-based detail design period lasting more than a year.

The main membrane manufacturer was the rubber company Continental, based in Hanover, Germany. The other main contender for work was Bridgestone. However, this company has a close relationship with Birdair, the US membrane designer and manufacturer, and it was felt that in order to avoid any possible conflict of interest or confusion about the source of the innovative ideas incorporated in the project, it would be best if a different contractor was used. Erection was undertaken by KOIT, a company experienced in membrane construction, under the guidance of Axel Thallemer who produced a detailed briefing document. Erection of the air-supported elements took four days. The building was built for 8% less than the original budget with all costs and progress continuously monitored in the same way as an industrial manufacturing project is controlled using computer-based prediction systems. Construction contracts were similar to those employed for the development of manufacturing components used in industrial production.

The initial response from the rest of the Festo company was mixed. The chairman, who effectively commissioned the building, liked it – the factory employees felt it was an irrational use of the

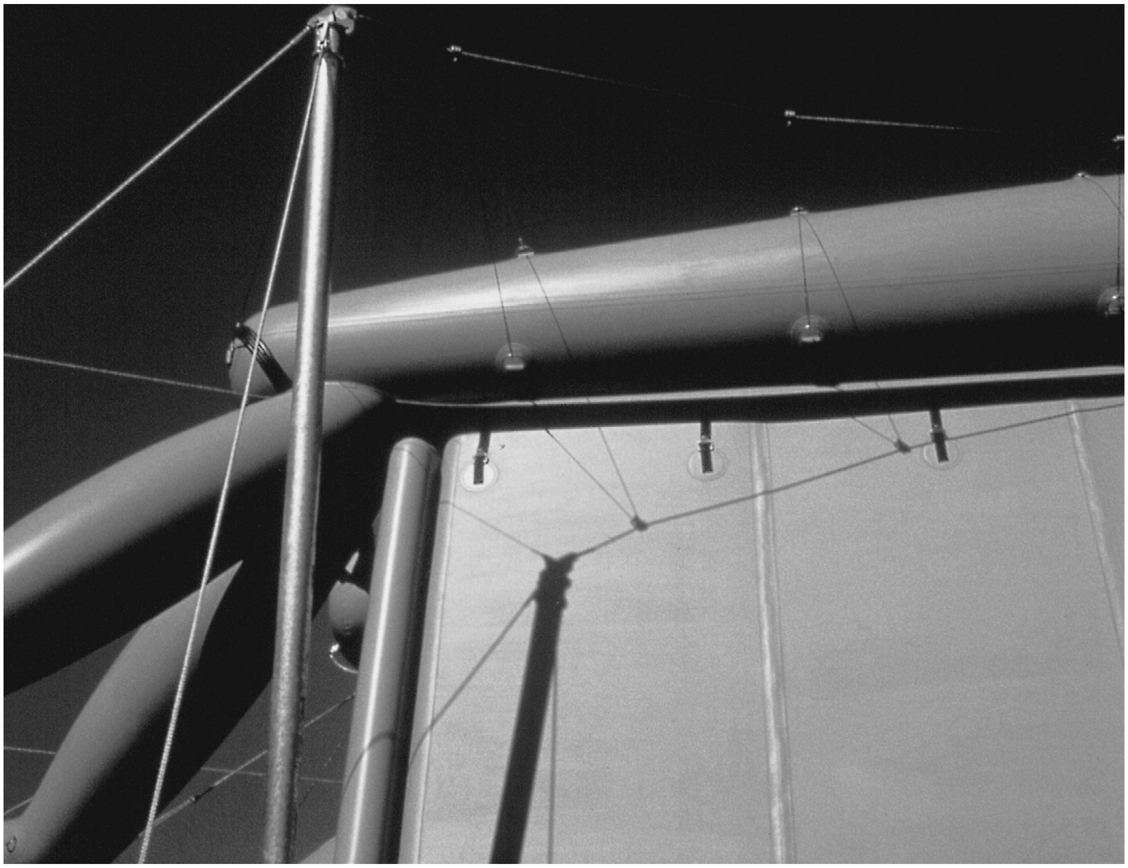

Fig. 4.10
Top corner of the end elevation.

company profits. Over time, the employees' suspicion has been replaced by pride in its achievements – many have had the opportunity to experience the hall at first hand, as it is not only used for exhibitions but also for seminars and meetings. Like many successful portable buildings, the duration of its siting has been extended, as the benefits of having a convenient physical example of the innovative nature of their product based permanently at the company headquarters is a valuable, easily utilised public relations tool. However, the original intention of a portable exhibition building that can communicate the company's skills throughout the world is a valuable concept and a second 'Airtecture' hall was completed in 2000.

This is the first attempt to make a building that is entirely self-monitored and self-controlled, its systems actuated automatically by computers and sensors. The objective has been to create an intelligent, dynamic architecture. An appropriate simile might be the comparison of a 'fly-by-wire' aircraft to a conventional machine controlled by hand through physically activated controls. The computer-based control system in a modern cockpit not only enables the aircraft to outperform conventional designs in manoeuvres, but it also makes possible dramatic innovations in airframe and power systems design.

The robust character of the external structure is an important part of the building's image – it has been described as a cross between a Gothic cathedral and a pumped-up muscle man (Fig. 4.11). Inside, the building hisses and clicks as the pressure valves open and shut in response to the commands of the computer. Though the continuous translucent panels that flow right around the building from wall to ceiling to wall are a relatively unusual feature, the overall interior space is formal and simple and therefore appropriate to the interior of an exhibition hall which should not have an architecture which distracts from the display (Fig. 4.12).

A computer terminal provides information about the temperature, air pressure and condition of every element of the structure and internal environment. Comparisons could be made to a wired-up astronaut whose vital signs are radioed to mission control because, similarly, the building's condition can be monitored anywhere in the world by electronic links through the Internet. Axel Thallemer admits that the control system, though

Fig. 4.11 'Airtecture' Air Hall exterior at its Esslingen site.

an intrinsic part of this experiment, would be too complex for a commercial building system. In the next stage of design development he would create a more simple regulation mechanism. Calculations have suggested that if the control system were to be turned off completely it would be more than a week before the building began to sag ... just a little. Despite the generous redundancy factor built into this particular system, active air-supported buildings could be criticised for the constant energy they require to remain operable. Though this is true for now, the responsive nature of the structural elements indicates that this project is just the beginning of a development route that will eventually lead to buildings that are designed to exactly match their loading criteria rather than, as now, to resist the worst possible conditions that may only ever happen once in their lifetime. Buildings that can respond actively to structural conditions in the same way that they already respond to temperature conditions – by the input of energy when it is needed – may result in a dramatic reduction in the material mass required to make them. A more physical advantage of 'soft' air membrane construction is that because of its flexibility it yields when subjected to impact damage, and that once the energy source is removed, the structure is demountable for storage or redeployment.

The 'Airtecture' hall has won many industrial design awards, including the Industrial Design Excellence Gold Award, the most prestigious US prize of this type. It has been widely reported in industrial design and technical journals and yet has made surprisingly little impact in the architectural press. Is this because it is so obviously an experimental design? An outcome of blue-sky research and development rather than the ultimate solution to a widely recognised pragmatic problem? The 'Airtecture' hall is indeed an experiment, one that takes its place alongside the 'upside-down' balloon and the flying inflatable wing, and perhaps for this reason has not yet been taken seriously by the

Fig. 14.12 'Airtecture' Air Hall Interior.

building profession at large. This is an important issue – if building contractors and component manufacturers do not take note of innovation, who will take the experimental results and apply them to the needs of industry? Festo have begun the design of a second building that will be used at EXPO 2000 in Hanover, Germany and they are also applying air-support technology to a new pneumatic structure incorporated into a permanent building to be erected at their headquarters in Esslingen. However, innovative technology cannot pass into use without general adoption by the building industry. The architectural profession needs to be aware of such developments and able to recognise their value and the relevance to the live projects to which they are asked to find solutions. Architects have long argued that each and every design project is, in a way, a form of research and development; however, if the work they do is not breaking new ground or supplying new information, this assertion is hard to justify. Genuine innovative research is risky, both in terms of the success or failure of the project objectives but also in terms of money expended for an unquantifiable return, particularly if the results do not find a viable market. Festo's return on their 'Airtecture' is as yet only quantifiable in terms of the company's improved image and increased publicity within the confines of their manufacturing industry market; however, its potential for use in live projects in the greater scenario of world construction remains untested. Much has been said about the possible benefits to architectural design of transfer technology from other industries – here is an example that contains several new technologies – pneumatic muscles, a transparent elastomer membrane, a woven three-dimensional double wall structure. In addition, these innovations are present in a built working example that is clearly workable in practical terms but also manages to communicate a provocative and exciting architectural form.

Airquarium, Germany

The most recent large-scale portable building designed by Festo is the 'Airquarium', a 32-metre diameter air-supported dome intended for use as an exhibition and event space. Lightweight membrane buildings that consist of a skin supported by a higher internal air pressure are not new – many enormous structures exist including permanent rooves that span huge sports stadia. However, Festo have taken a typically innovative approach to this building type pushing back its performance capabilities in a number of areas.

The new Vitroflex membrane is unique in several ways. It is remarkably translucent (it could even be described as transparent) for such a large air-supported structure – combining structural strength with a high degree of connection to the

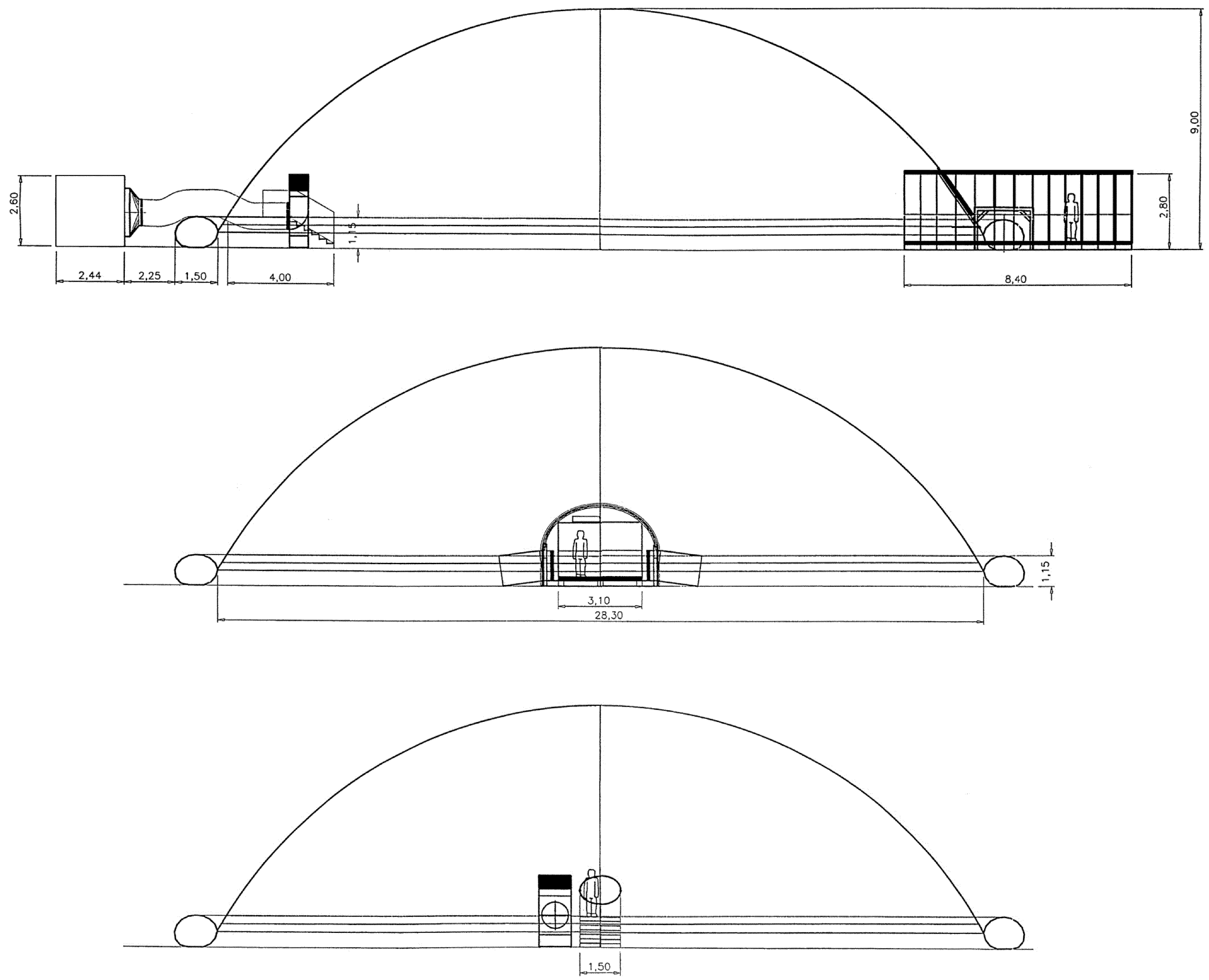

Fig. 4.13 Plans of the 'Airquarium' in deployed form.

world outside the dome was a key aim of the Festo design team. In addition, this synthetic material has been refined so that in case of fire only a non-toxic vapour of water and vinegar would be released.

The building consists of a simple hemispherical dome that is 9 metres high when fully erected, restrained at the base by a tubular torus which is filled with water to form a stable foundation. The main airlocked entrance cuts through the torus and is big enough to admit large vehicles – there is a secondary entrance that crosses over the torus for pedestrians. The entire structure is carried in two 6-metre standard containers. One holds the modular maintenance units for air-conditioning and ventilation, a water exchanger for heating and cooling, a weather station with thermostatic control and wind-load dependent air pressure control and emergency generators that allow the building to operate completely independently for up to 48 hours. The other container transports the dome, the airlock and the foundation membrane.

The building can be installed on any solid ground surface and takes six people a week to erect, though much of this time is taken with filling up the foundation ring with water. 'Airquarium' is intended for use as an exhibition hall and event and function space, and has travelled to many

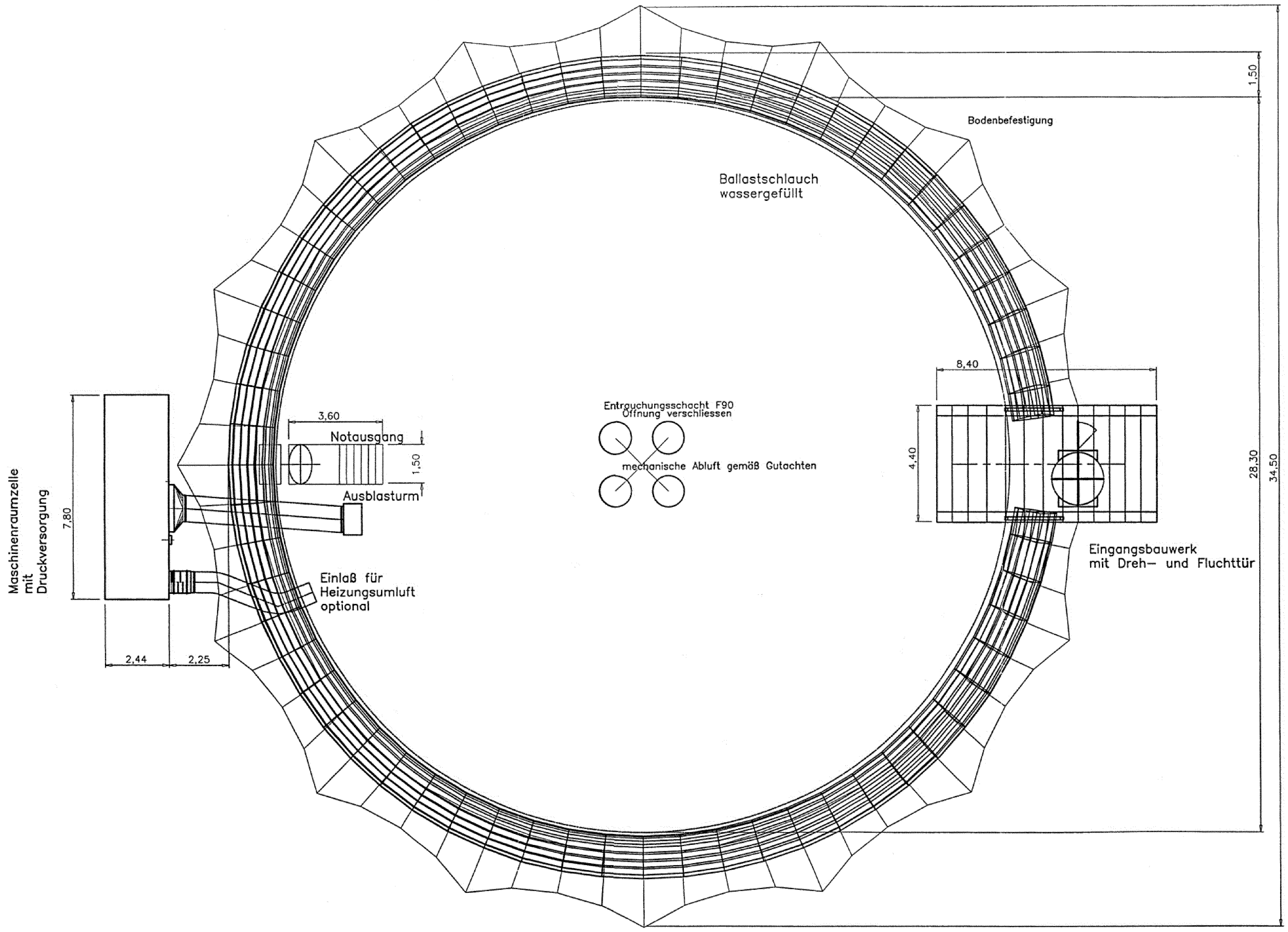

Fig. 4.14 Plans of the 'Airquarium' in deployed form.

Fig. 4.15 'Airquarium' in use as an exhibition hall for 'Fifty Years of Italian and German Design' in Bonn, Germany, 2000.

Fig. 4.16 'Airquarium' in use as an exhibition hall for 'Fifty Years of Italian and German Design' in Bonn, Germany, 2000.

Fig. 4.17 'Airquarium' outside Festo headquarters for the company's 75th anniversary.

venues in the three years of its existence. Plans are currently being developed to license the production of similar structures with varying dimensions for use world-wide.

Further reading

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West McLaren Mercedes Team Communications Centre

Date: **2000–2002**
Client: **TAG McLaren Group**
Designers: **TAG McLaren Group**
Contractors: **TAG McLaren Group (with specialist subcontract coachbuilders)**

Formula 1 motor racing is the most glamorous sport in the world – its blend of money, speed, and danger is undoubtedly responsible for this. However, there is also the factor that each race takes place in a different location to the last, ensuring a constantly changing exotic backdrop to the drama on the track. The Formula 1 tour is often likened to a circus, and in some ways this description is appropriate. It is a travelling form of entertainment that transforms each location that is visited to a temporary Mecca for the media, fans, and the countless shops and catering outlets that service such events. If it is a circus it is one in which dozens of different acts must perform in unison, with different objectives and agendas. Behind the glamour and the razzmatazz is a sport in which a team's success is based primarily on the application of remarkably high degrees of engineering design expertise and the equally complex effective communication of their sponsors' messages. Formula 1 success is a balance between the first-class engineering required to get the cars on the track, and the first-class management required to convince sponsors to provide the funds to do it.

Fig. 5.1 The paddock at Belgium's Spa Formula 1 Grand Prix racing circuit. West McLaren Mercedes vehicles line up to the rear of the pit lane with tyre racks stacked ready for the race.

Fig. 5.2 The West McLaren Mercedes Team Communications Centre.

Though each team has a permanent base from which to manage its operations, carry out the testing of components and build the cars, races can only be won at the circuit – to transport the complex operations of a multi-million pound engineering and business management company from place to place every two weeks throughout eight months of the year is a daunting yet essential task. Surprisingly for such a design-based industry, it is only in recent years that highly specialised vehicles have been considered as a way of solving these problems and the latest evolution is the West McLaren Mercedes Team Communications Centre, which exhibits all the skill and style of their creator's experience.

A Formula 1 team's circuit-based operations fall into two distinct areas, the pit lane and the paddock. The pit lane is where the racing cars are prepared, stored and serviced. Pit lane vehicles are always coach-built on commercial standard chassis' configured to transport the cars and all the spares and equipment necessary to keep them running during practice, qualifying, and race day. Though these vehicles are expensive, sophisticated, and well-built travelling workshops, there is no fundamental requirement for them to be more than lorries because the crews are provided with standardised pit lane buildings in which to work on the cars. However, some have been provided with an integral awning system that opens out to provide a covered area immediately behind the garage. In addition, vertical fabric panels are used for privacy, as much of the technology of Formula 1 must remain secret from other teams in order to maintain their competitive edge.

The paddock is where all the remaining back-up operations take place. These are incredibly diverse. There is an administration function, not only for the race taking place at that venue, but also for other upcoming races, and because senior management personnel also travel to the races, it is

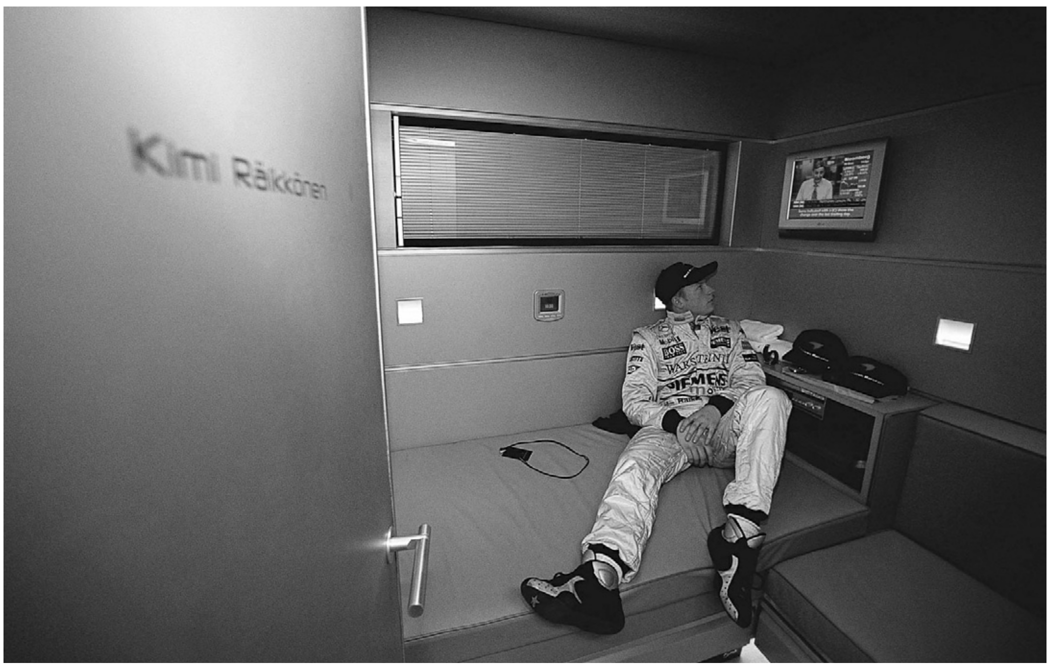

Fig. 5.3 Driver's rest area – both drivers have their own dedicated rest area.

necessary to continue managing the business happening at the team's home base. This is a very complex task because a Formula 1 racing partnership will not only consist of the car designer and manufacturer but an engine supplier and team sponsors. These organisations work very closely together but have distinct identities, so they need to communicate effectively and immediately with their bases which are often in different countries, perhaps even on the other side of the world.

The team's paddock facility also needs to provide a base for the drivers, engineers and team managers as they develop race strategy and tactics. This is a place where they can review and discuss confidential information on what is happening to the cars and the circuit. This is often in the form of detailed telemetric feedback regarding the performance of the team's cars but also more general information on what is happening to their competitors. Drivers also need a private place to rest, clean up and mentally prepare if they are to perform at their best.

This is the minimum brief for a Formula 1 team paddock facility; however, there are other functions, which are also desirable. Communications are not only limited to in-house requirements – the media is a very important part of motor sport, providing the mechanism for its continued funding in terms of race broadcast commentary, advertising, spin-off sales and related events. There is global interest in every aspect of Formula 1, from the excitement and drama of the race itself to the personalities of the drivers. Although each Grand Prix has an FIA media centre, facilities are also provided to support the peripheral activities of the dedicated television, radio and print-based journalists who are present at every event.

Entertainment is a very important part of the communication requirements of each team – sponsors, VIPs and journalists must all be made welcome and comfortable – visiting the paddock and brushing shoulders with drivers and media personalities is all part of the excitement of race day and a reasonable reward for companies and individuals who have invested heavily in their belief that their chosen team can win. In addition, there are the hard-working engineers and pit crew who need to take rest and refreshment breaks if they are to do their best.

This sophisticated brief has previously been achieved within the confines of a converted motor home with understandable compromises in performance and function. Typically, the team, engine supplier and title sponsor will each have their own separate vehicle – not an ideal situation for a partnership that must work closely together and present a unified presence to the outside world. The

Fig. 5.4 The atrium space – the hub of the West McLaren Mercedes Team Communications Centre.

Fig. 5.5 View of F1 paddock from balcony of West McLaren Mercedes Communications Centre.

varying functions are contained in a narrow, linear plan form, often with low ceilings and minimum space allowances. Because these facilities are created on vehicle chassis the 'ground' floor area must be elevated up to a metre high to clear the coach's running gear. The larger areas used for dining and entertaining are provided by marquee-type awnings set up adjacent to the vehicles. These are difficult to heat and cool and impossible to separate-acoustically from the very noisy trackside environment.

It was West McLaren Mercedes' Team Principal, Ron Dennis, who first set out to change this pattern by commissioning a more sophisticated structure that would blur the boundaries between vehicle and building. Dennis is one of the primary dynamic forces of the TAG McLaren Group, an energetic, respected leader who is involved in every aspect of the team's business. In 1996 TAG McLaren built the first paddock motor-home which, once on site, could not only be self-levelled to provide a stable platform, but by the push of a button could be extended even higher to form a second floor. By the next season, many other teams had followed McLaren's lead and created similar facilities. West

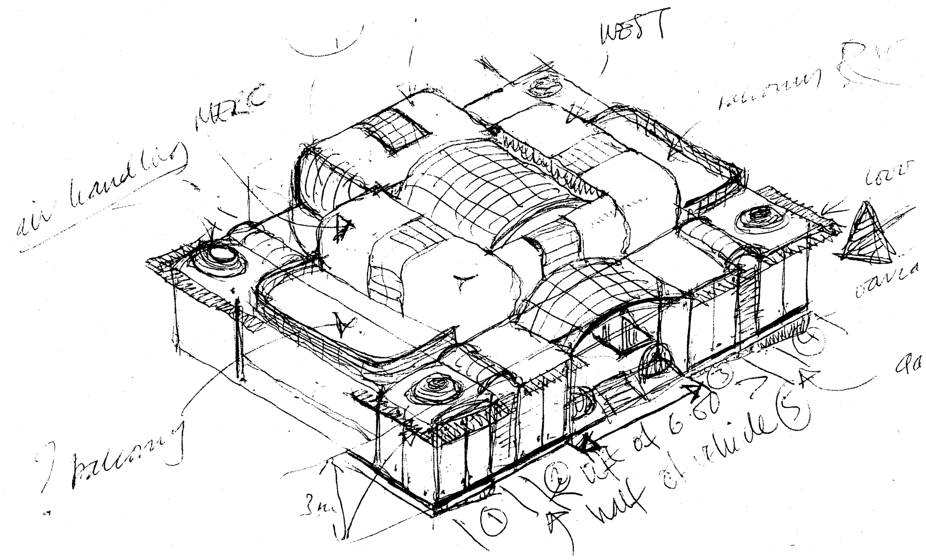

Fig. 5.6 Preliminary sketch design.

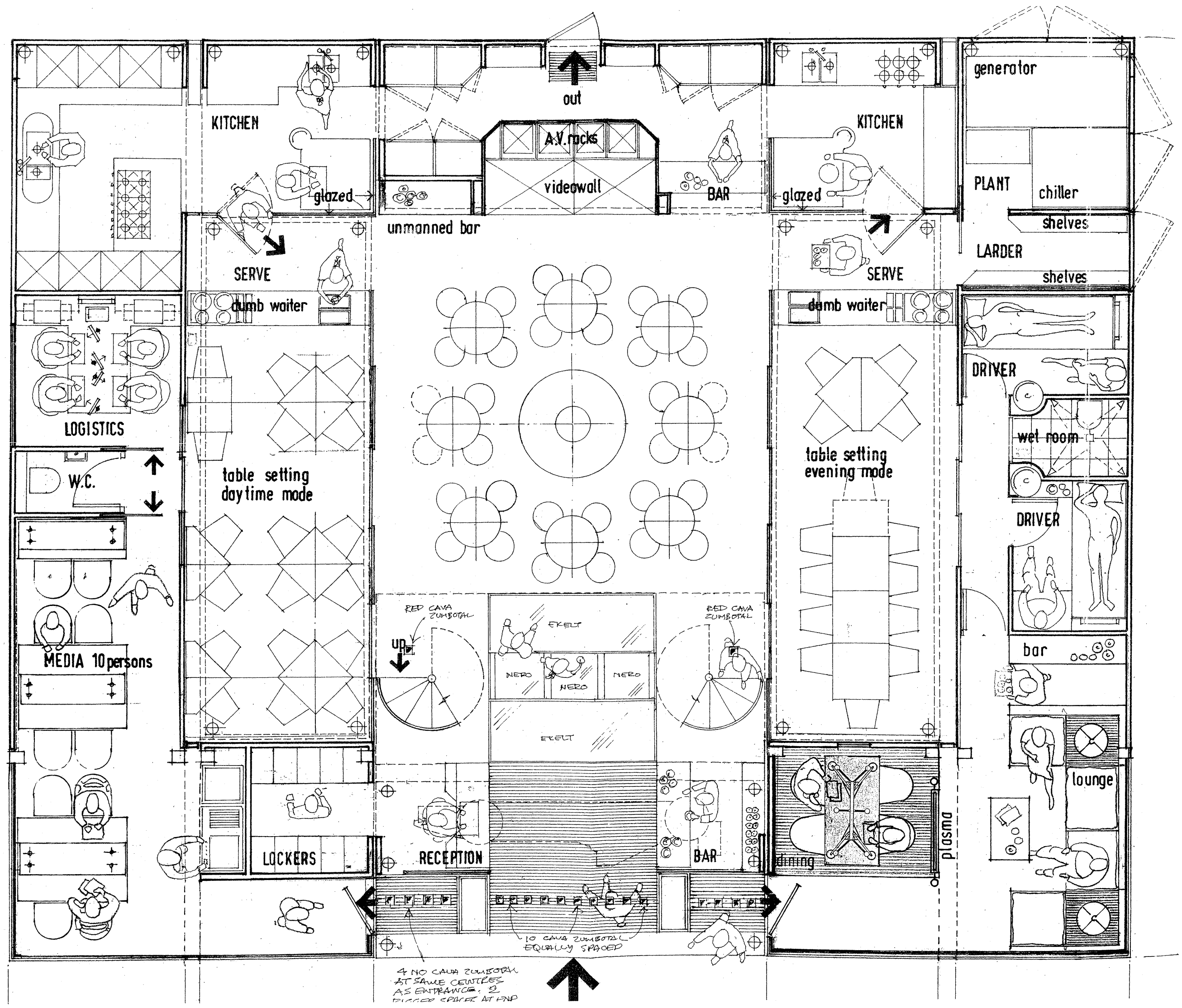

Fig. 5.7 Ground floor plan.

McLaren Mercedes' current facility, the Team Communications Centre, will be a much more difficult act to follow as it is such a quantum leap forward in both functional ambition and technological expertise.

The commission for the new facility was instigated at the beginning of 2000 in response to Dennis's belief that the method of operation within the three existing separate motor homes had become outmoded. The complex relationship between the three main team elements: title partner West, engine manufacturer Mercedes-Benz, and McLaren, was at risk of being undermined by the inability of the three separate paddock facilities to cope with increased integration. There was a space for meetings but once these were over, people retreated to their separate bases. However, the demand for a new design concept went beyond the functional – McLaren wanted to create a coherent design image for the paddock facility that would communicate the team's philosophy of open partnership and innovation.

Though there are no architects within TAG McLaren's design team they have a pool of talent which has extensive experience in designing all kinds of buildings from standard commercial housing to bespoke high quality one-off projects. Working with a specialist coach-building firm who had direct experience of designing and building Formula 1 support vehicles, they produced the

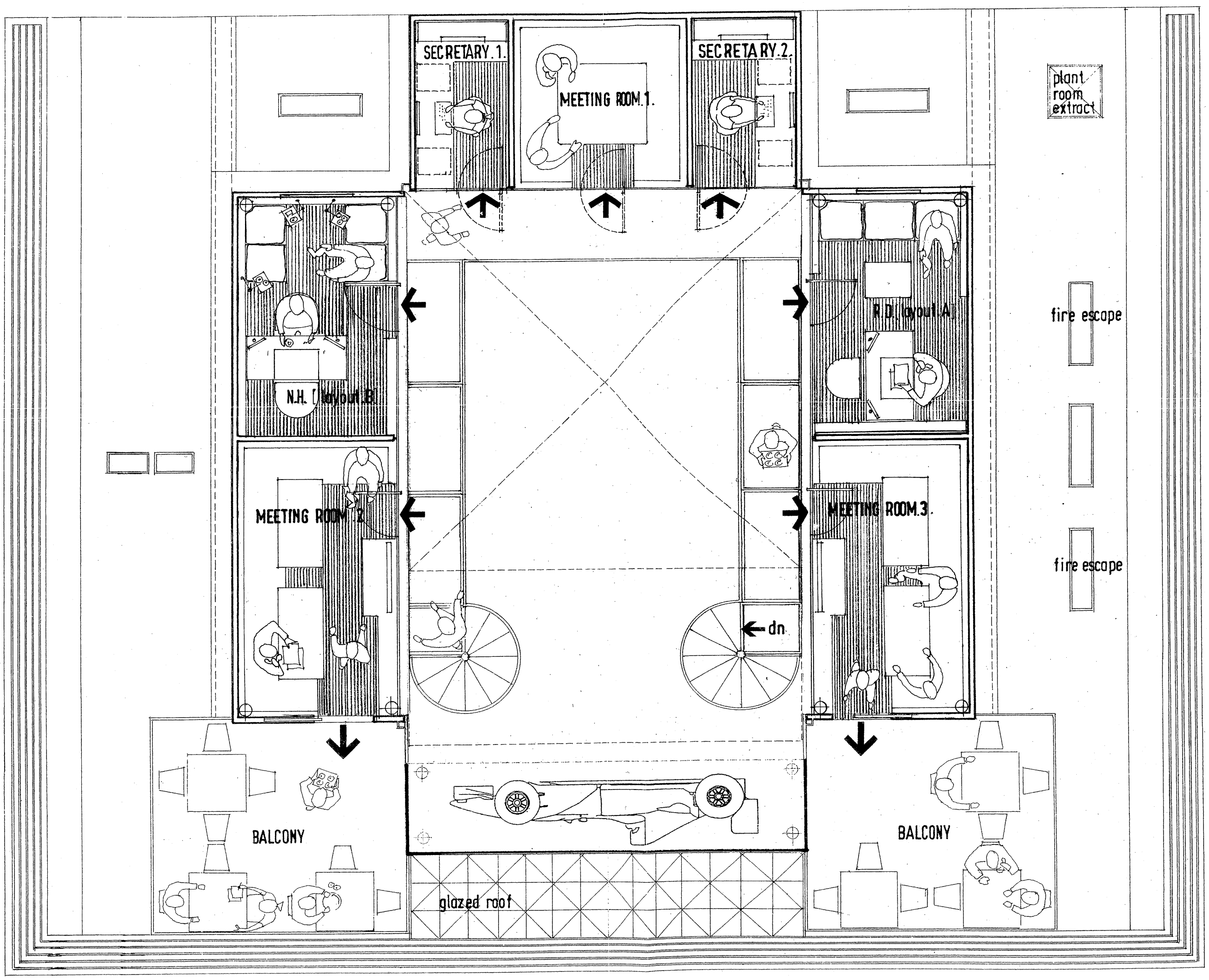

Fig. 5.8 First floor plan.

elevating roof motor-home design. Not surprisingly, Dennis turned to the same in-house consultants to create this more ambitious development. After meetings and briefings the design team, working in collaboration with the coachbuilder, very quickly produced a prototypical idea that gathered a series of prefabricated 'cabin'-type structures around a central atrium. The peripheral components would contain the offices, meeting rooms, communications rooms, kitchens and services and the central space would be a double height entertainment and dining area. Key members of the design team flew out to the French Grand Prix at Magny Cours over the weekend of 28th to 29th June 2000 and worked virtually non-stop for 48 hours developing the design in more detail with the valuable on-site experience of a typical race weekend. Over the following month more detail was added to the concept and a realistic physical model commissioned. Eventually it was this model that sold the design to West McLaren Mercedes, Dennis immediately recognising that the objectives he sought could now be realistically achieved.

The completed building layout is remarkably similar to this initial idea; however, the detail of how it could be achieved is significantly different. The building is organised around a central atrium, which is used as an entertainment and dining area seating 68 people at one time and serving more than 200 meals per day. At first floor level there is a walkway accessed from two spiral staircases, one on either side of the main entrance. Also on either side of the entrance is a receptionist and a small bar. At the rear of the atrium are the kitchens, two more bars and two dumb waiters. Access to the ground floor side wings is by doors on either side of the main entrance. To the left are the communication and logistics facilities, to the right the drivers' area with a small private rest room for each driver, a shower, and a combined lounge/private dining room that can also be used as the team engineers' office and the drivers' briefing room. The most private facilities are upstairs: offices for Ron Dennis and Mercedes-Benz's Norbert Haug, personal assistants and meeting rooms, though

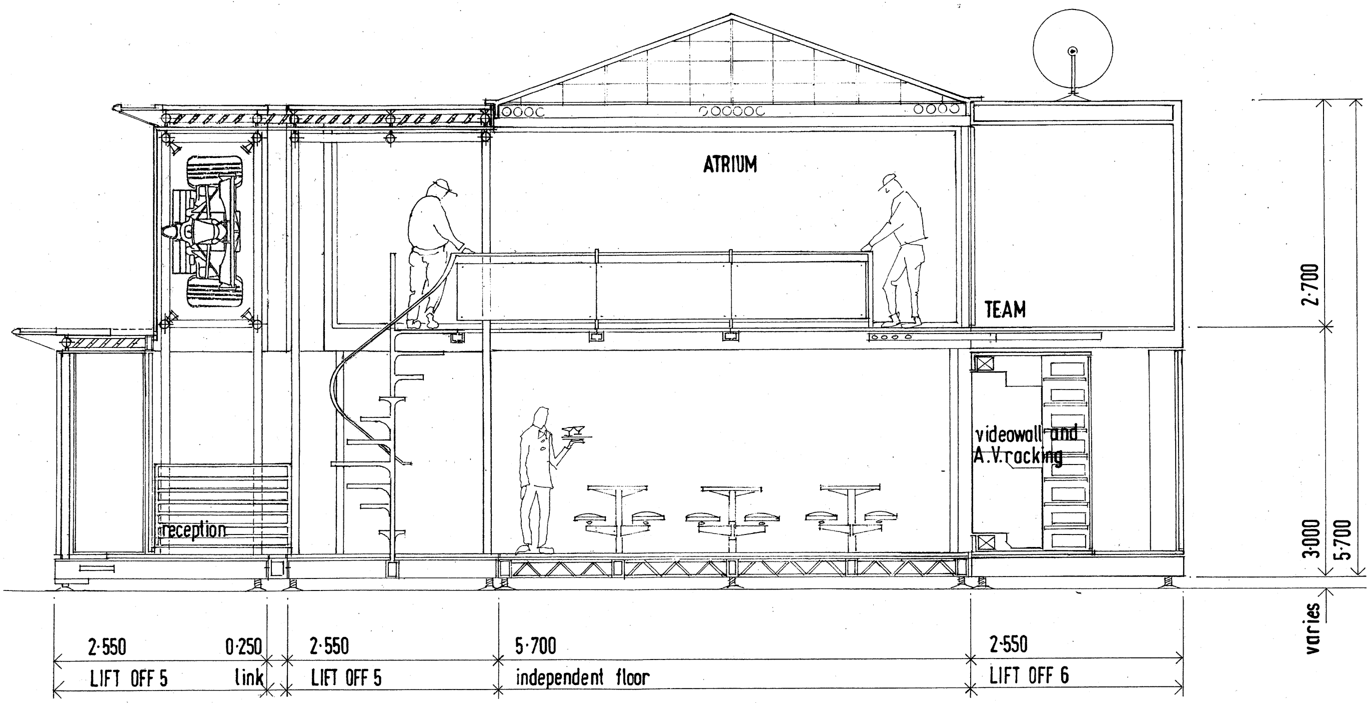

Fig. 5.9 Front to rear section.

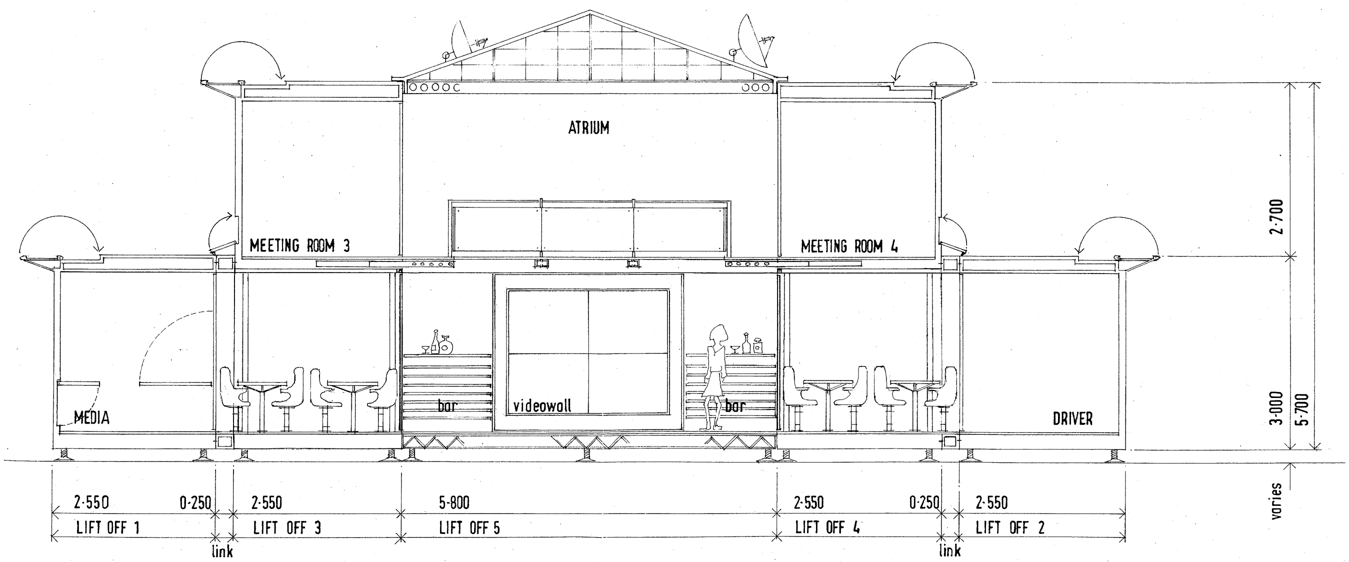

Fig. 5.10 Cross-section.

Fig. 5.11 Private meeting/dining room.

there is also an external balcony which, because of its elevated position, can also provide a view of the track at most circuits. The building provides a working base for the two most senior officers and their personal assistants, various team management personnel, two drivers, ten engineers, four chefs, eight catering staff, and ten marketing/public relations people from the team and its partners.

The building's plan is formal and axial with clear demarcations between public and private. What is remarkable about this design is that it is a building that is created from a number of readily dismantled portable elements. The initial idea to base the portability strategy on the assembly of a series of 'cabins' that could be offloaded from lorries and dropped into place next to each other, proved to be just the starting point for what had to become a much more sophisticated design if it was to work as the team wanted. The design intention was to integrate the different components of the West McLaren Mercedes organisation – in order to do this the building must operate as an integrated system. Physical access between the different 'cabins' had to be easy and instantaneous, as had electronic communication between the different parts of the building and the pit garage and the various bases in England and Germany. Extensive communications systems, office equipment, kitchens, bathrooms, etc. all add up to a highly serviced building that would also need sophisticated climate control systems. This might possibly have been achieved with a variety of temporary solutions with a transient appearance; however, for this extremely image-conscious engineering company such an approach was not acceptable. The facility had to work excellently but it also had to look excellent too – and as the intention was to create a fully working office/media building away from home this was the image it should convey.

An important restriction on the design was the paddock restraints, which are established by the Formula 1 governing body. The dimensions of the space that each team has to set up its facility are rigidly defined – a straightforward method of building within the restrictions and simultaneously making sure that the most is made of the available space has to be found. Other problems are typical of those found for any transportable structure – road restrictions in both height and weight, how to deal with services such as water storage and disposal, the demands for manpower, special equipment, and safety requirements during deployment. It was also stipulated by McLaren that although the new facility would be expected to do much more than the previous one, its cost of operation and the number of people involved must be the same.

Fig. 5.12 Communications area.

Fig. 5.13 Erection process. Top; pod 1 is in place and pod 2 is being placed alongside, middle; pods 1, 2 and 3 in place, bottom; pods 1-4 in place and pod 5 being positioned.

All these factors led the designers to adopt a more sophisticated approach to the individual accommodation components (now called 'pods') which they detailed so that each would plug directly into the next, making the building appear and perform as one unit once assembled. Although the building consists of eleven distinct elements, once they are assembled, they become for all intents and purposes a single entity. The pods are constructed on a steel frame for strength and rigidity, clad externally with insulated matt aluminium panels or glass. There is a small glazed canopy over the entrance, and over the central atrium there is a double skin polycarbonate pyramid roof made from the Kalwall system. The floor of this central space is made up of fibreglass beams whilst the upper walkways are made of non-slip etched glass. The internal wall panelling is aluminium or glass and all pod floor and ceiling panels can be removed for access to lighting, air-conditioning and communications wiring. There is a remarkable sense of openness in the central atrium space, not only because of the translucent roof and glazed entrance, but because of the detailed handling of the meeting rooms and offices on each side. These have fully glazed walls only partly obscured by etched panels, which consequently allow glimpses of important work in progress by the key members of the West McLaren Mercedes team.

The facility is moved around Europe on six dedicated lorries. The assembly process begins with the first pod, which is set up on the carefully marked out site using laser levels for millimetre accuracy. The pod is brought in on its dedicated lorry which is parked carefully in position – all subsequent pods will be matched accurately to this one so no errors must be made as they will be duplicated as assembly proceeds. The pod feet are extended horizontally and then rammed down by its own integral hydraulics system to raise the pod and allow the lorry to back away. The rams then move up to let the pod settle to the ground. Once resting on the ground the feet are moved horizontally back into the structure and then the rams operate again to level the pod out just above

Fig. 5.14 Hydraulic rams concealed in the floor locate the pods accurately.

ground level. Once this first pod is in position the next is brought alongside, set at the same height with its feet sitting on oiled plates laid on the ground. The second pod is linked to the first via steel connectors which are powered by the hydraulic rams to pull it on its oiled plates to plug into the first. This process is repeated for each consecutive pod. Numbers one and two form the left wing, and number three the rear wall. The fourth element is lifted onto the structure of number three by the crane built into one of the lorries. Number five forms the front wall entrance and number six is extended above this by the integrated hydraulic system. Numbers seven and eight form the right wing. The ninth and tenth elements extend upward from number one and number seven also using in-built hydraulics. The final element is the pyramid roof, pre-assembled on the ground and then placed into position by the crane. The lorries also have built-in turntables to allow for easy positioning of the pods. The spiral staircases are intact units, the steps winding down around the core for transportation – the first floor walkway slides horizontally out of the pod structure. The external eaves lighting elements hinge out of the top surface of the pods and a gutter hinges out of the wall of the upper elements to cover the gap between the rooves.

All electronics are transported in-situ as are the fax, copiers, printers, coolers, kitchen equipment, etc. A number of these are dedicated systems developed in conjunction with McLaren Team technology partners (for example, Siemens Mobile who provide the telecommunications equipment, and Canon who, as an official supplier to the team, supply communications peripherals). Movable items include chairs, tables, the reception and front bar, and the dumb waiters. Once the main building elements are erected it is connected to external services such as electricity, communications, telemetrics and water. Hot and cold water tanks are filled and land connections for communications and power are made. The building is, however, truly independent with two 7.1 litre diesel generators (with 1000 litre fuel tank) which operate all the on-board equipment including three linked air conditioning chillers. Typically, the building works on one generator plus a mains electricity landline. The kitchen ovens are propane powered and wet waste is taken to a holding tank which is emptied at a motorway disposal centre once the building gets back on the road after the weekend's events.

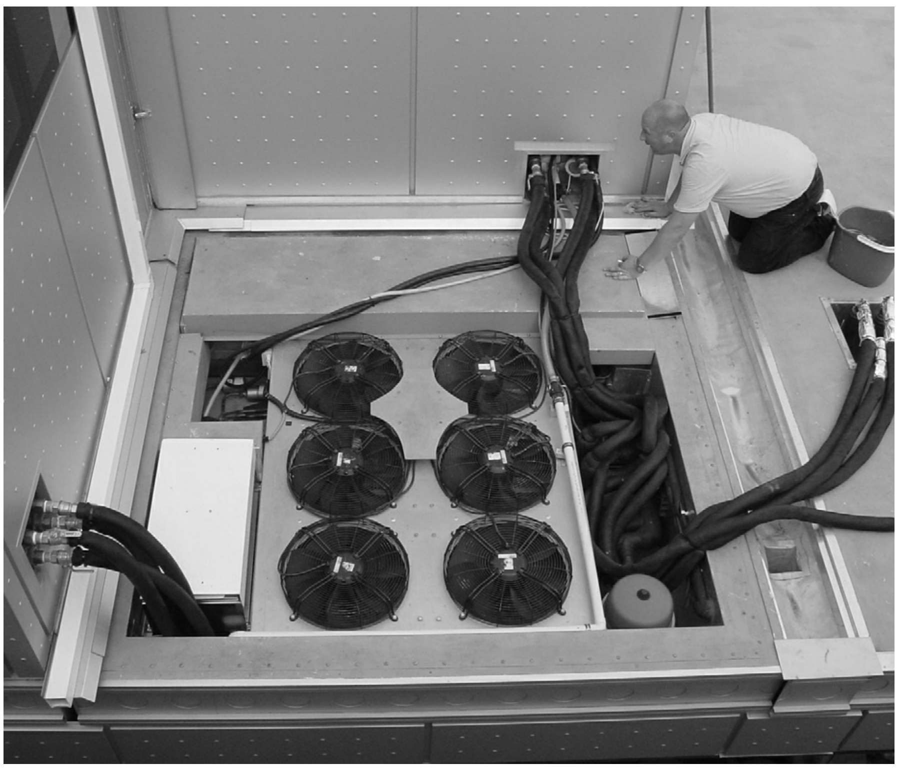

Fig. 5.15 Air-conditioning plant is located in the roof of the lower pods.

The erection process is carried out by six drivers and two technical engineers supervised by the facility's Technical Manager. All personnel are used for the manual labour required to commission the building, including laying out furniture, the stocking of bars, kitchens, bathrooms, and the endless cleaning and polishing that is an essential part of all the Formula 1 facilities – the motor homes need to shine as much as the cars, and it makes no difference that the West McLaren Mercedes Team Communications Centre is a full-sized building. Though this extensive commissioning process takes a day and a half, the building assembly takes just 12 hours to set up and 12 hours to take down. It is used for every Grand Prix that is practicably reachable by road, which currently means all those in Europe. It has a design life of five years and although it has been declared a

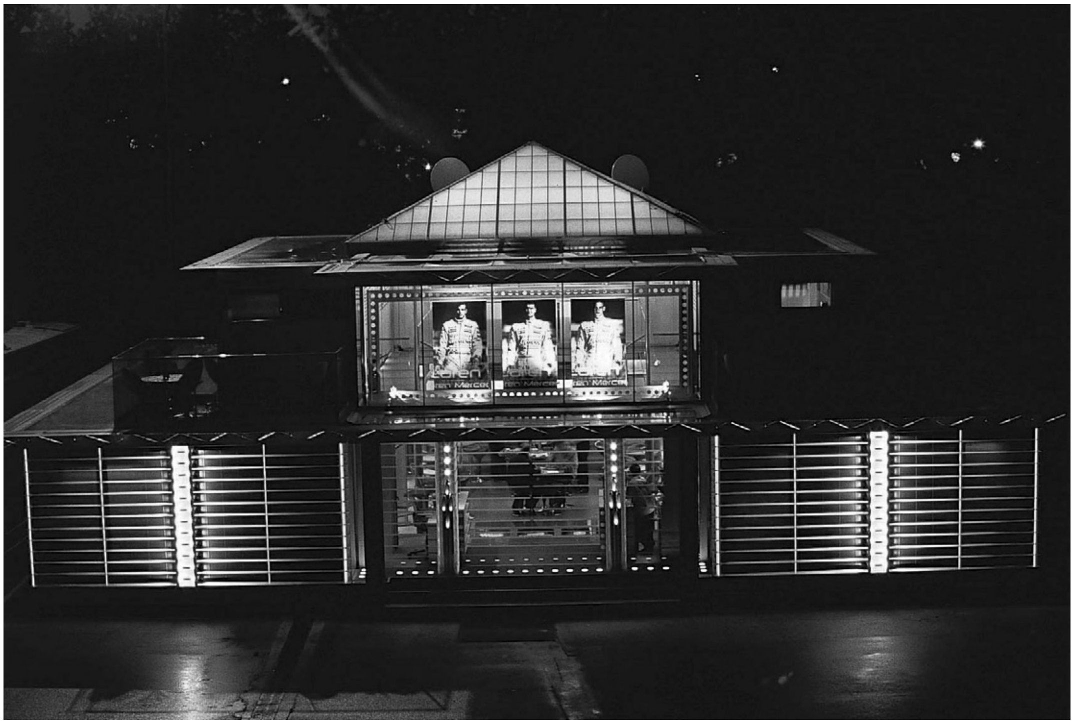

Fig. 5.16 Night view.

success after its first year, such is the importance of innovation and the awareness of image for this client that it is entirely possible that a new and more ambitious facility may then be commissioned to take its place.

The design team and the coach builder produced independent cost estimates based on their experience of the previous expanding motor-home project with additional costs factored in for the new complexities, and then compared them in order to reach a final budget. The building commission was based on a set of drawings and a specification of what would be produced and a contract was entered into one year after the commission was first received. The coachbuilder produced all the engineering drawings and no structural engineers were involved; trust being placed in physical testing of all structural components prior to final assembly. The projected construction period, including all testing and commissioning, was nine months, and although this was extended by eight weeks, the building was completed on budget and in use for its critical target date at the San Marino Grand Prix at Imola in April 2002 when Bloomberg – one of the world's leading news and information organisations – announced their involvement with the project to become an official partner of the Team Communications Centre.

The external appearance of the West McLaren Mercedes Team Communications Centre is sleek, modern and engineered. There is no doubt, however, that this is not a vehicle but a piece of architecture – its structural basis of transportable pods cannot be guessed at from either the outside or the inside once it is erected. The designers are candid that it was their ambition to create an image for the building that reflected the engineering prowess of the TAG McLaren Group operation, and they used various methods to achieve this. There is no doubt that the construction and deployment strategy results from practical considerations, but the use of comparatively tough and rigid structures not only helps the building withstand the rigours of thousands of miles of transportation and multiple deployments, but also gives the building a solidity that is commensurate with the desired image. Some elements, such as the external horizontal louvres in front of solid panels and the pod feet 'covers' are superfluous in terms of function but have been added to contribute to the overall character. Nevertheless, this is a portable building that is both innovative in design detail and functional in operation. Ron Dennis is emphatic that his intention was not to create a new 'publicity' object but to build a working tool with a very specific functional task to fulfil. Testimonials from those who use the facility, including hard-to-please journalists, leave no doubt that the main objectives of usability and openness have been achieved.

The paddock of a Formula 1 Grand Prix circuit had, until the 2002 season, been a setting solely filled with purpose-built though conventional coaches and trailers, each painted in their teams' colours. The West McLaren Mercedes facility is completely different in almost every way. It is a facility that works to encourage a collaborative working atmosphere. It has a welcoming image for visitors yet also provides privacy for confidential meetings and respite from the crowds. It combines intensive working facilities for a wide range of purposes with high quality arrangements for entertaining and pleasure. It maintains an extremely highly serviced physical environment in diverse weather conditions combined with the latest in communications and engineering monitoring equipment. It delivers these qualities at the place and at the time they are needed thereby providing the ultimate support for the users' work ambitions. To do this in a conventional building structure is a worthy achievement, but to do it in one that can be erected or dismantled repeatedly in just 12 hours is remarkable.

Further Reading

'Team Building' in *Racing Line*, the official TAG McLaren Group Magazine, June 2002, pp. 16–21.

PART 2
Problem Solvers

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Trustee Savings Bank (TSB) Mobile Bank and Hospitality Facility, UK

Date: **1991**
Client: **Trustee Savings Bank and the Russell Organisation**
Architect: **Apicella Associates, London, UK:** Lorenzo Apicella
Engineer: **Atelier One, London, UK:** Neil Thomas
Contractor: **The Russell Organisation, Norwich, UK**

Hong Kong Tourist Association Pavilion (HKTA)

Date: **1995**
Client: **Hong Kong Tourist Association and the CP Group**
Architect: **Apicella Associates, London, UK:** Lorenzo Apicella, Janes Robson, John Massey, Hilary Clark, Kate Darby, David Gausden
Engineer: **Atelier One, London, UK:** Neil Thomas
Contractor: **Brilliant Stages, Greenford, Middlesex**

Volvo Car Mobile Marketing Units

Date: **1997**
Client: **Volvo UK and the Russell Organisation**
Architect: **Apicella Associates, London, UK:** Lorenzo Apicella
Consultant: **Touring Manager,** Peter Whiting**, The Russell Organisation, Norwich, UK**
Contractor: **The Russell Organisation, Norwich, UK**

Exhibition design is usually perceived as a separate discipline from architectural design. Many examples are variations on a standard product, and even dedicated projects are often made by specialist companies without professional design input. However, there is a creditable catalogue of specific exhibition designs that have influenced the direction of architectural development, and many important architects, from Charles Rennie Mackintosh to Zaha Hadid, have worked in the field. The scale of exhibition stand design is wide, from modest presentation panels for internal use to large-scale external spaces that incorporate lighting, audio-visual, and environmental control systems. A common factor is that all are temporary, and many, because of their relatively high investment, are designed to be transportable so that they may be used at many venues over several seasons.

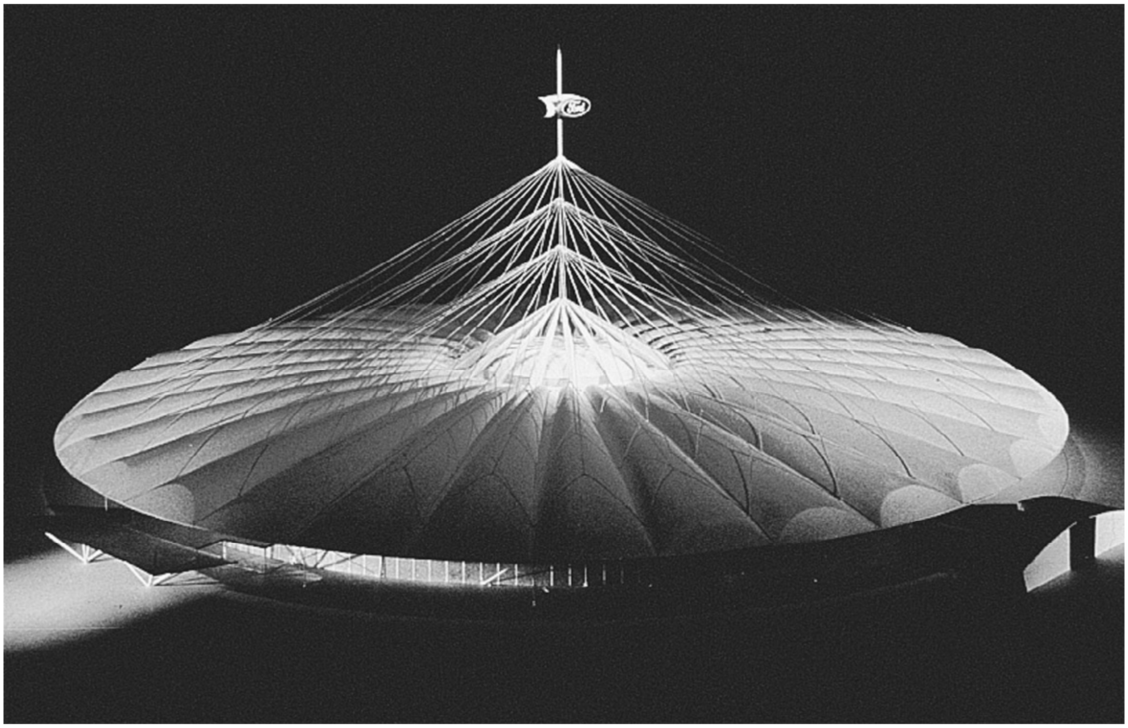


Fig. 6.1
Design for a touring exhibition and conference hall for Imagination by Lorenzo Apicella and Neil Thomas, 1989. This 13,000 square metre building was to utilise a pneumatic envelope supported by a central mast tensioned and braced at the perimeter.

Architect Lorenzo Apicella has completed several innovative designs in this field. Though these structures are not permanent, he believes that the principles involved in their design relate directly to architecture – his exhibition stand designs have benefited from his architectural skills, and his approach to the design of conventional buildings has evolved through the experience gained in his temporary work. Before founding his own architectural firm in 1989, Apicella worked for SOM in Houston, CZWG architects in London, and the design company Imagination. In 1986, whilst working at Imagination, he designed a series of complex transportable display stands in collaboration with Buro Happold engineer Neil Thomas (who founded Atelier One in 1989). These exhibition stands were designed for marketing purposes at car shows and did not have to accommodate the

Fig. 6.2
Lorenzo Apicella design for Imagination, Ford of Europe exhibition environment, 1993. A mobile, multi-faceted stand used for a four-year pan-European travelling programme.

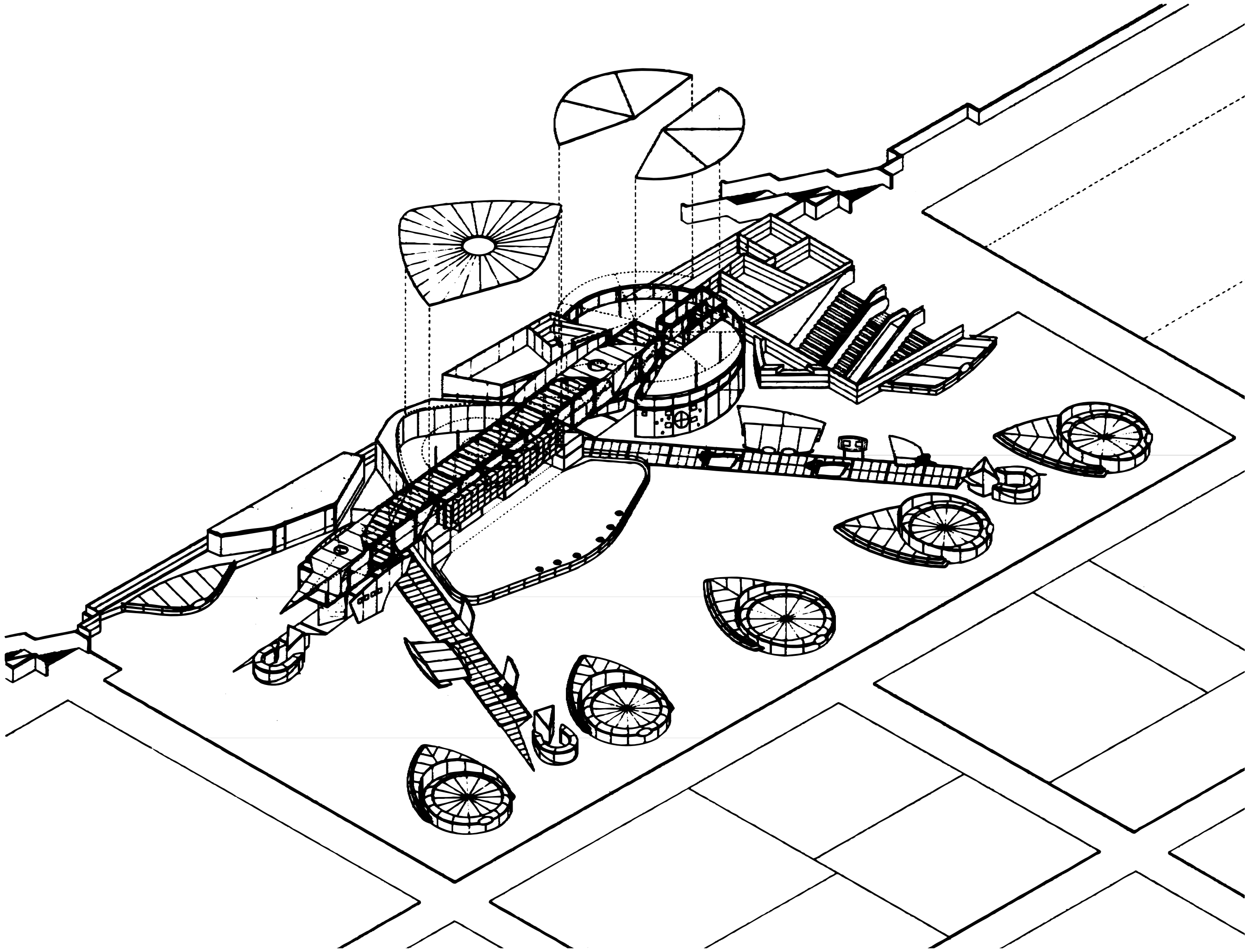


Fig. 6.3 Ford exhibition stand at the Geneva Motor Show.

difficulties of environmental modification that is usually a prime determinant in shaping built form. In 1988 Thomas and Apicella collaborated on a project for a major American car manufacturer that took this factor as one of the main concerns in generating its form, though it too was for a completely portable exhibition (see Fig. 6.1). The clients wished to hold a series of large conferences at different locations throughout North America and were seeking a way of providing an identity within a range of commercial exhibition halls. A problem with such exhibitions is that the client must not only compete with other adjacent stands but also with the image of the venue itself. Apicella and Thomas therefore created a concept for a completely mobile venue that would not require a separate protective enclosure. The building would not only provide the functional space required for the conferences but would also create a definitive image of elegance and technology for the company. Their proposal was for a 13,000 square metre, virtually column-free structure, which because of its flexibility would be capable of use for all kinds of events. The membrane structure spanned 135 metres, was 12 metres high at the centre and 6 metres high at the perimeter. It took the form of a pneumatic disc that was suspended by cables from a central mast and restrained at the edges. Once inflated, this structure provided its own rigidity. This project fundamentally questioned the client's brief and was therefore never realised. However, the concept of a completely independent portable building was to be realised in later collaborations between Apicella and Thomas.

In 1993 Ford of Europe required a stand to launch their new model and a four-year, pan-

European exhibition programme which would open at the Geneva Motor Show and then tour to other similar events throughout Europe (see Figs 6.2–6.3). In a venue which would contain a wide range of exciting products and exhibition systems in competition, it was imperative that the Ford display stood out from the others and attracted as many journalists and members of the public as possible. Working in collaboration with Imagination, Apicella developed a concept for a kinetic stand that would support an 'event' which would be repeated at twenty-minute intervals throughout the entire show. The event would include the movement of several full size vehicles and would need to be sufficiently flexible to accommodate different venues and layouts. As well as these ambitious operational objectives, the entire 2500 square metre stand would also need to be portable and be capable of installation in not more than five days. Apicella's design approach was to create a completely pre-manufactured series of elements which could be varied in layout from venue to venue but would always convey a kinetic, technological theme synonymous with the image of the car. The stand was designed as a series of large objects in order to reduce the assembly period. The two main elements were a veerendeel girder with glass walls and floor, which was transported complete with its lighting, and a video wall which formed the backdrop to robotic platforms that moved cars around the display area. All the main elements were moved into place using either a standard fork-lift truck and/or manpower. The stand also included a production room from which the ten-minute programmed performance was controlled. The Ford of Europe stand relied on lighting, audio and a blend of transportable architectural elements combined with complex stage production techniques to create a dynamic and novel environment.

TSB Mobile Bank and Hospitality Facility

On the strength of a conference presentation that he made on the theme 'designing on a budget', Apicella was approached by the production company Town and County (now the Russell Organisation) to work on a project for a mobile bank and hospitality suite for the Trustee Savings Bank (Fig. 6.4). Though the clients knew that they required a mobile facility they were not sure what form it would take and therefore asked several companies to submit proposals for the work. Apicella's objective was to create a sophisticated pavilion, which when fully assembled would acquire its own image as an elegant building. The client had considerable previous experience of customised standard units and was able to prepare precise operational requirements for the design. Despite the fact that the exact sites that the unit would occupy were not known, the clients could specify their general nature – outside shows, exhibitions and public events – and through knowledge of their customers were also able to target quite accurately the type of person who would use the building. Out of season, the facility would be used for training courses and hospitality events for TSB's own staff around the UK. A logistical brief was developed which determined that the pavilion should be capable of erection in no more than two days, by a maximum of four people, and the cost of a single deployment including transportation and erection should be no more than £4000. The pavilion had to contain sophisticated equipment and accommodate its occupants' activities and remain operational when remote from mains services, regardless of the external weather conditions. The project had a particularly short programme for such a complex brief and was to be taken from design to completion without prototypes in less than seven months. It was to have a minimum lifespan of five years. Apicella collaborated with the production company to develop the brief further, investigating materials, components and systems which could reduce the effort required in the erection process but would also result in a form that clearly had integrity as a high-quality building rather than a temporary shelter.

Apicella's solution was to design a structure based on a standard 13.5 metre long articulated lorry trailer which could be towed from site to site easily within the constraints of transportation regulations (Fig. 6.5). The trailer base was used for the lower floor and four hydraulic rams (one at each corner) lifted another 'Russian doll' structure directly above it to form an upper storey. Terraces and canopies could then be unfolded and pushed out from the main structure to articulate the facade and provide extra space. Once in position the expanded structure was locked into place and the new floors levelled and stabilised with fold-out adjustable legs. A cashier's unit was positioned on the lower floor which could be rotated through 180 degrees to allow this area to be used in a number of different ways. Upstairs, a hospitality suite with access to an open-air balcony was serviced via a dumb waiter from the lower level kitchen. The glazed skin adjacent to the lower floor terrace could be fully retracted in good weather. A support vehicle carried furniture, erection tools and components, and an on-board generator provided power and light for the building when remote from mains services. Other services included heating and cooling plant, adjustable ambient and task lighting and two remote control, audio visual display units.

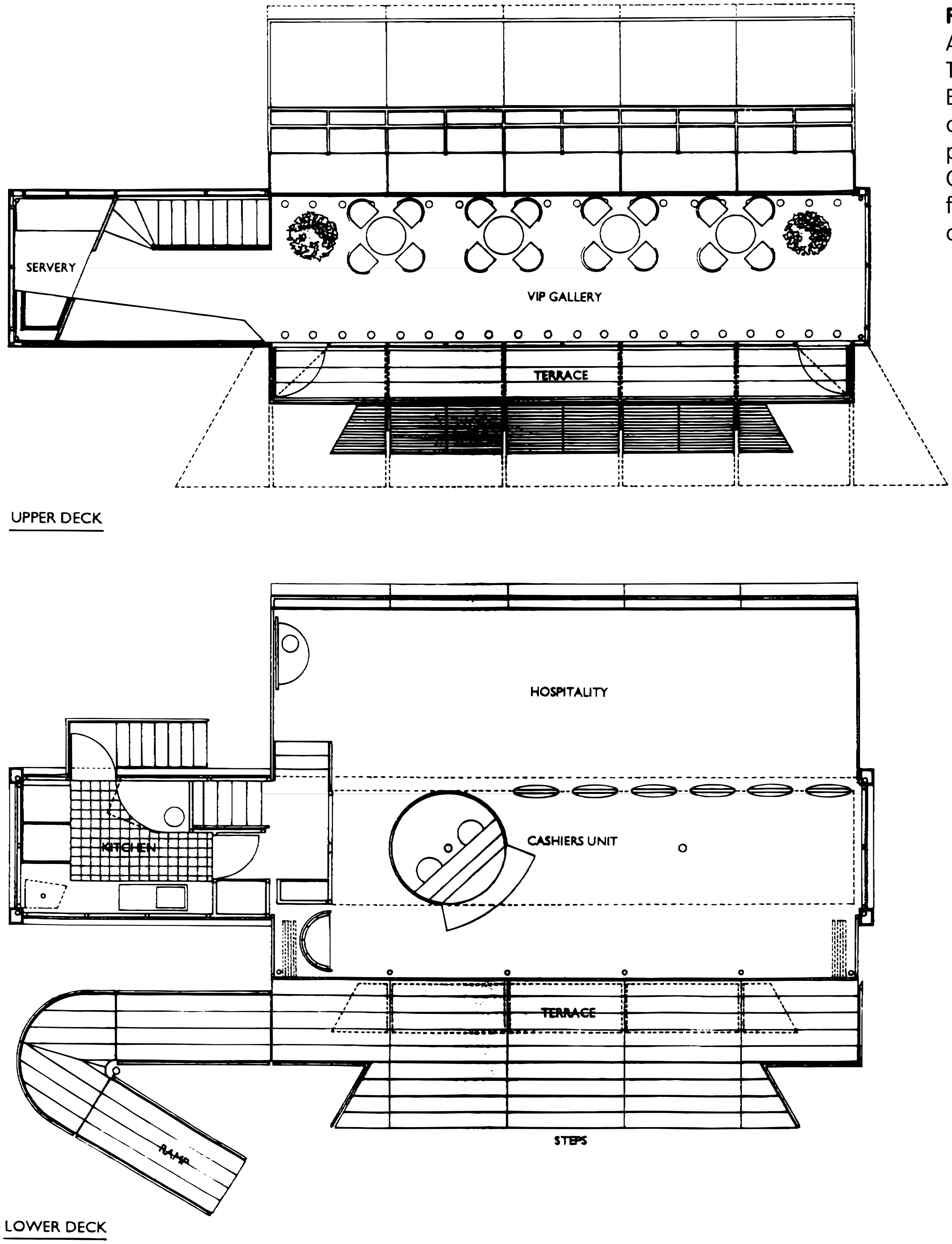


Fig. 6.4 Apicella Associates, Trustee Savings Bank mobile bank and hospitality pavilion, 1991. Ground and first floor plans in deployed form.

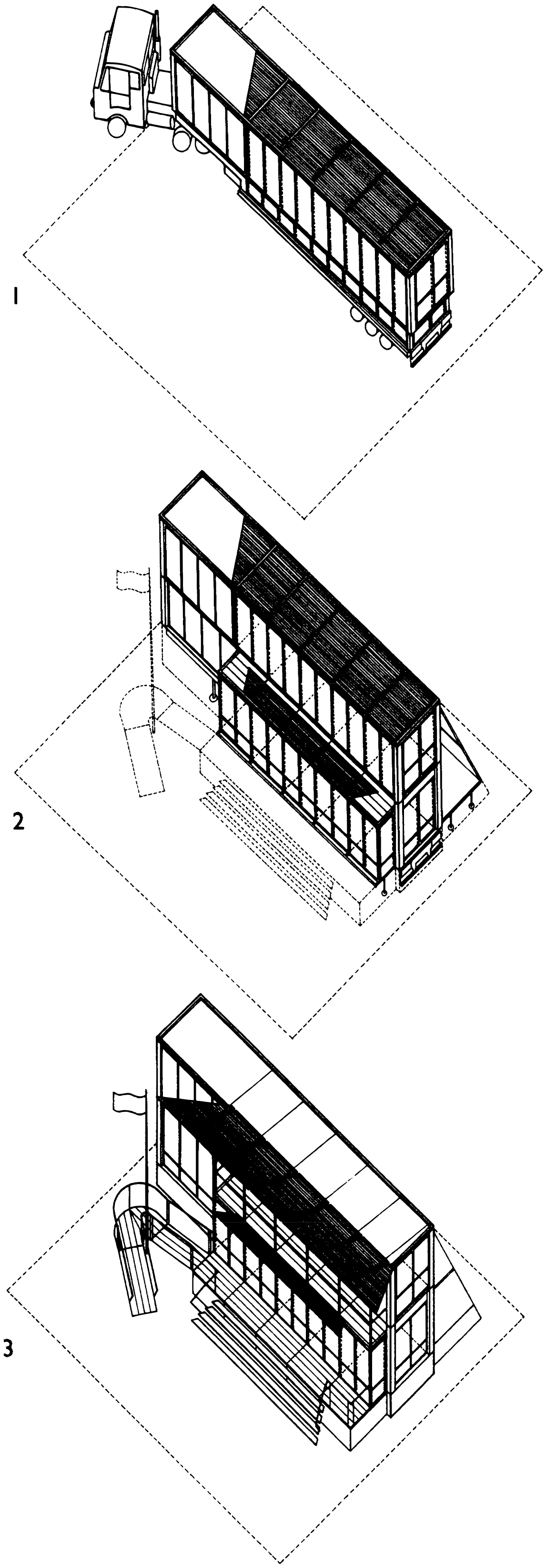


Fig.6.5 TSB pavilion erection process.

The main hydraulic erection procedure could be carried out in just twenty minutes and two riggers could complete the remaining tasks in eight hours. This transparent, delicate object, camouflaged its basic lorry trailer structure effectively and the overall image was of an elegant lightweight building (Figs 6.6–6.9). After dark, the illuminated interior became clearly visible providing the visitor with enticing views of the pavilion's activities.

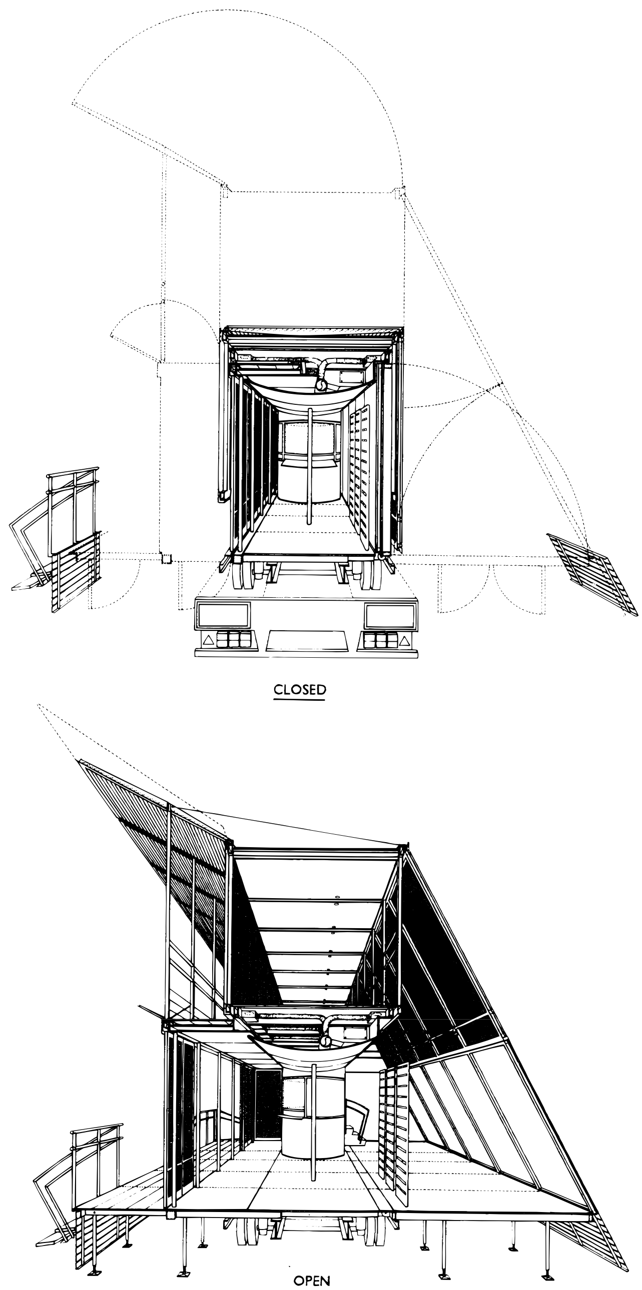


Fig. 6.6 TSB pavilion. Top: closed for transportation, bottom: open for use.

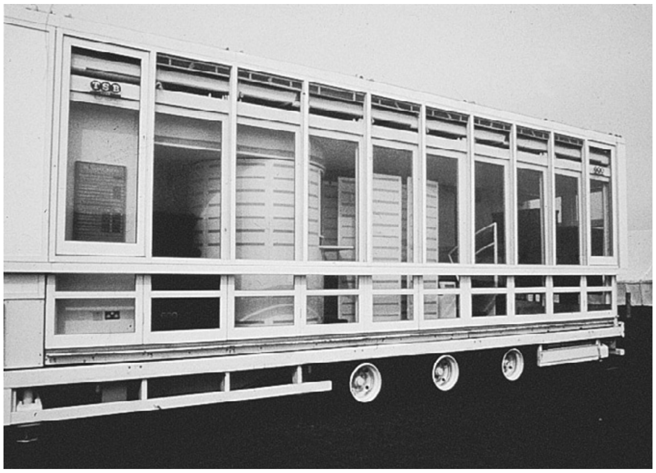


Fig. 6.7 TSB pavilion, trailer in transportation form.

Fig. 6.8 TSB pavilion with the entrance elevation doors open.

Fig. 6.9 The trailer base is hidden in order to reinforce the image of a building.

In this project Apicella used his knowledge of exhibition design to incorporate moving hydraulic components, though he also consciously selected building products such as aluminium curtain walling in order to reinforce the architectural image of the pavilion. The construction of the project was quite different to normal building operations. Neither did it use coach builders, who are normally used for building specialist body trailers, as they had little experience of demountable and movable components. The main contractor was Town and County (now the Russell Organisation) which was experienced at organising exhibition events and erecting mobile displays. They subcontracted the project to a series of specialists which included a stage and set production company, accustomed to building hydraulically operated kinetic structures. Building industry sub-contractors were used in certain areas (such as Glostal for the curtain walling) and Apicella states that all who were involved in the project expressed interest in its novel design aspects and tried hard to achieve good results. The architect's involvement with the design was far more intensive than with a similar sized conventional project where standard solutions and manufacturers' details can be utilised. Of the two pavilions constructed, one has been sold on to the marketing division of car manufacturer Volvo, which subsequently asked Apicella to investigate other mobile building possibilities (see Case Study 6c).

Hong Kong Tourist Association Pavilion

This travelling pavilion was a design development of the earlier TSB project, though for a different client. The initial brief was for a travelling venue that would tour European cities and promote Hong Kong as a tourist destination. The Hong Kong Tourist Association's original concept was for a Hong Kong tram car specially prepared for transportation and supported by additional exhibition material. This was a rather modest concept that tended to reinforce a clichéd view of the city and Apicella suggested that a purposely designed structure would present a more accurate and exciting impression (see Fig. 6.10). The success of the earlier TSB pavilion was an important factor in convincing the client of the viability of this larger and more complex project. Apicella's experience was especially valuable in that the project management and production company, the CP Group, did not have the experience of Town and County in this particular type of project.

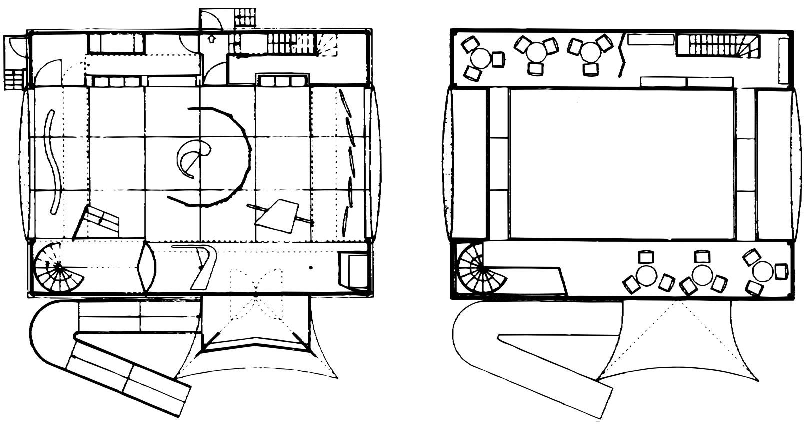
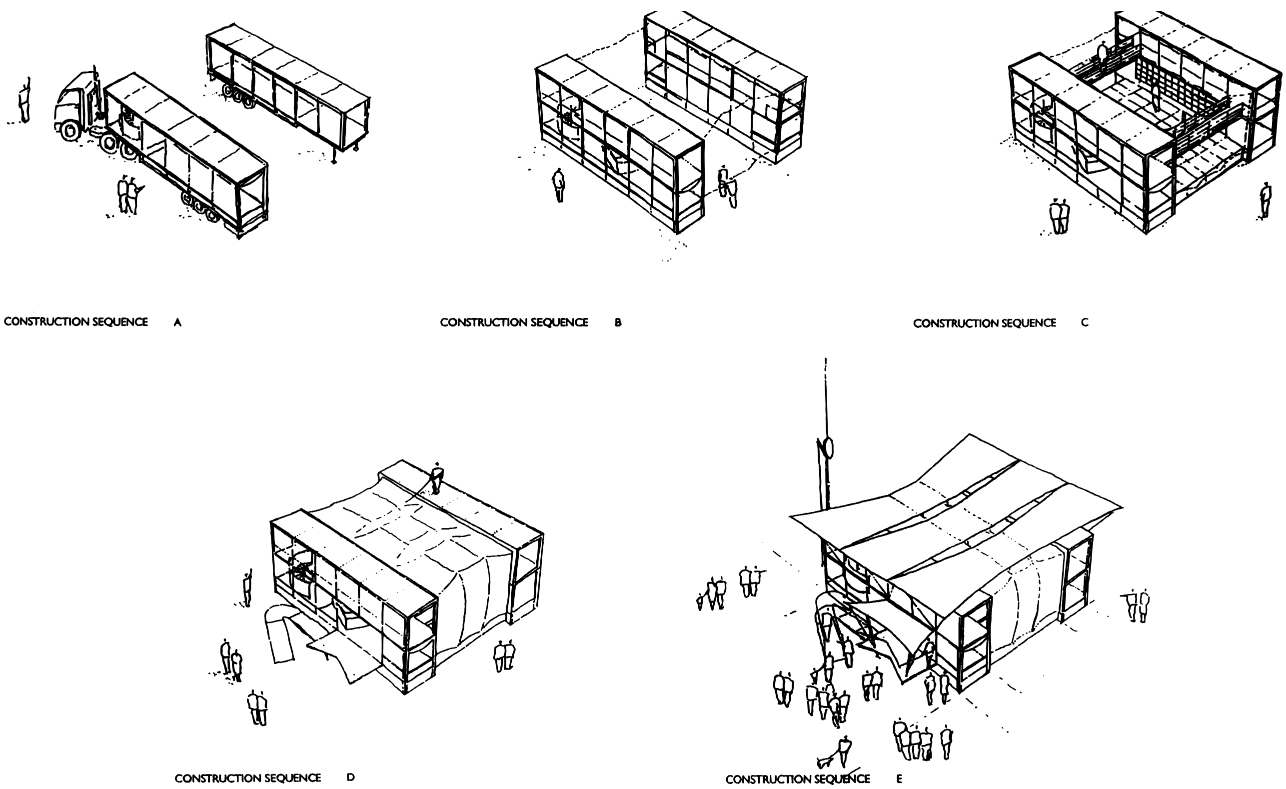


Fig. 6.10 Apicella Associates, Hong Kong Tourist Association pavilion, 1995. Ground and first floor plans in deployed form.

Fig. 6.11 HKTA pavilion, erection sequence



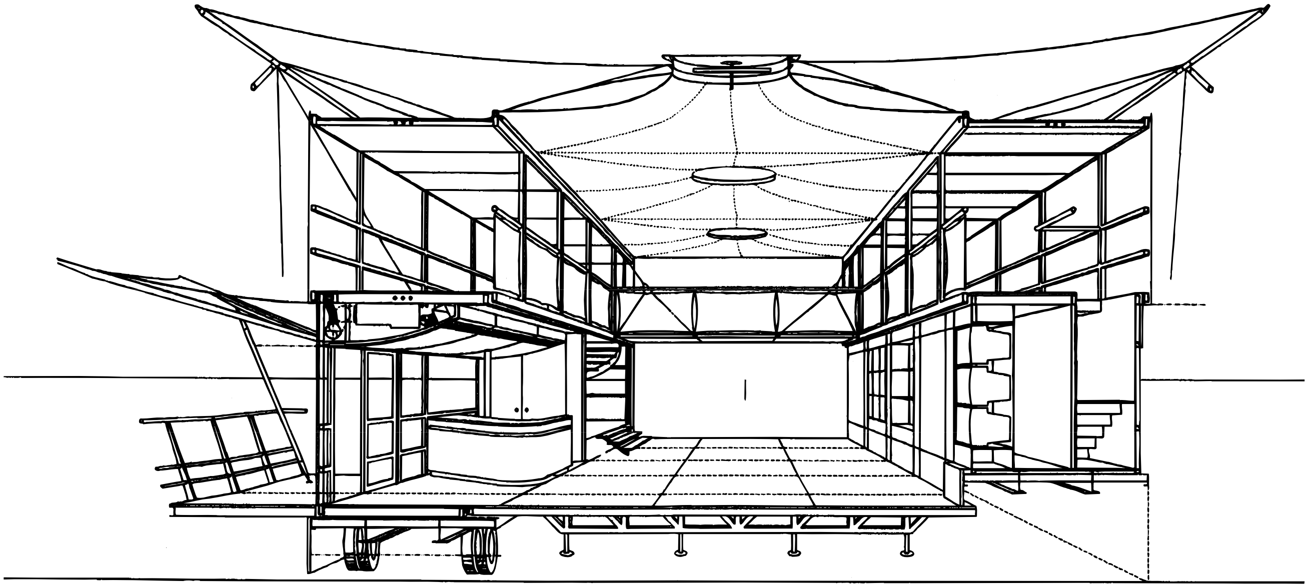


Fig. 6.12 HKTA pavilion cross-sectional perspective.

The pavilion is transported in three standard 13.5 metre long trailers, two providing the main structure for the building and a further one carrying furniture, separate building components, tools and the generator and air-conditioning plant. The pavilion can be fully erected in twenty-four hours by a team of six operatives and uses a combination of automatic and hand-assembled procedures (see Fig. 6.11). The erection process follows a set sequence. The first trailer is set into position and levelled using a special system that incorporates greased shoes that allow fine adjustment of lateral movement and accurate positioning in relation to the second trailer. The central floor space is hydraulically deployed from each trailer and has aluminium trussed support beams. Bridges provide circulation at first floor level and also brace the entire structure. As with the TSB pavilion, the upper level spaces are automatically erected using hydraulic rams located at each corner, then locked into place when fully extended. A continuous roof membrane which is carried separately in the support vehicle is threaded around the perimeter edge of each unit and drawn into position after the main structure is assembled.

The original design for the project was based on summer use only; however, changes were subsequently made to the design to allow the pavilion to be used in winter (Fig. 6.12). In the initial proposal, the building would have suffered from condensation problems in cold weather as warm moist air inside met the relatively cool single skin membrane. This was therefore redesigned to be a twin skin system into which warm air is pumped. This not only heats the roof volume but also provides structural rigidity. A third membrane skin provides solar shading and is suspended at roof level between fold-out aluminium frames. External ramps, a mast and internal video wall, and exhibition panels are all carried in the support vehicle as are crew facilities including changing rooms and showers (see Fig. 6.13). The pavilion is intended to take part in an extremely intensive programme, visiting fifty European cities during a 320-day tour each year.

The HKTA project has several significant differences from the TSB pavilion. Though it used ramp and balcony extensions, the earlier project consisted of a space which was restricted in size and shape by the trailer which formed its structure. The HKTA trailer uses the structure in quite a different manner, as the beginnings of an elemental modular system that embraces new space, unrestricted by the road width size of the trailer (see Fig. 6.14). If required, this philosophy could be extended to make infinitely larger spaces by the juxtaposition of additional roof membranes that still utilise the same trailer-based structural system. Despite its larger size, the HKTA trailer is simpler in construction, the main innovation being the pneumatic roof membrane. The deployment procedures have been made less sophisticated in order to meet

Fig. 6.13 HKTA pavilion, Apicella Associates, entrance elevation

budget restrictions, though this means that more personnel are required and the process takes longer. As with the TSB pavilion, the publicity tour organisers did not know the exact locations where the building would be deployed, though they had decided on the type of site – city centre squares, parks, and gardens. This general information helped the designer develop an image for a building which would not be out of place in these situations. Similar contractual arrangements were used to the earlier project, utilising a combination of specialist stage manufacturers and conventional specialist building component suppliers. One innovation was the use of refrigerated lorry chillers

Fig. 6.14 HKTA pavilion, internal view from the first floor.

for air conditioning, a transfer of technology from vehicle engineering.

In this project, Apicella developed the brief from the client's original modest intentions into a truly innovative building. The client's response to the use of innovation was positive in that they appreciated the value that such a dramatic event structure would have in terms of their own marketing and promotional objectives. The budget, though controlled, became flexible when it was understood that much more could be achieved than was originally supposed, and that greater value could be gained from a more ambitious project with a higher capital expenditure. Running costs associated with transportation, erection and servicing replace the normal costs of site and mains services connections. Projects such as this are therefore budgeted on a capital and running costs package based over a given time period and though this building may be more expensive per square metre than a conventional one, it has greater value because of its flexibility.The prime benefit is that the facility can be taken directly to the people it is intended to reach. It also has the valuable advantage of flexibility in that location and operational factors can be reassessed during the building's lifetime and altered according to new requirements. A facility which can be used anywhere at any time can obviously be used in many ways which a conventional building cannot, in particular, its independence means that it does not need to be restricted to trade fairs and exhibitions established within other structures.

Apicella's approach to his portable exhibition designs has been to decide clearly on the purpose of the building and then create a structure with an appropriate image. The construction details and the buildability of the solutions are crucial factors in their effectiveness, but they have not dictated the image. His work is not a slave to the logistical problems of deployment, nor is it a structural essay dependent on the construction. The architect has been intimately involved in the construction details throughout each project, and these have been developed in response to erection procedure requirements as well as aesthetic objectives. As time and budget did not allow for prototype construction it was essential that these structures worked first time, which meant taking extreme care at the design stage and relying heavily on the experience of specialist contractors in the resolution of difficult details. This is especially so in the many situations where details are of a kinetic nature and have to operate successfully each time the building is erected. It is therefore of special interest that the buildings did not change in a conceptual way once the design was accepted by the clients, though design details developed considerably as component and materials specialists became involved.

Apicella believes that this type of building design is different from more conventional work in that it is object-centred (the object being the building itself) rather than contextual. Though the designer knows the type of site in advance, the actual physical and environmental characteristics are unknown. It is the economic and strategic concerns of the marketing exercise planner who determines the general locations, and the experience of the riggers who locate the building precisely in its site. Any contribution that the building makes to the understanding of its situation must therefore be to a great degree both coincidental and ephemeral. Its contribution to the long-term development of the city grain may only be in that it presents a new possibility for a space that alters visitors' perceptions and perhaps introduces them to new possibilities not realised before.

The portable buildings that Apicella Associates have designed have such complex operational characteristics that they have required a much more intense involvement by the designer. There are very few standard details, and consequently every element must be considered with great care, working through the detail, not just in three dimensions, but also as a process which will be erected, operated, dismantled and transported again and again. However, the benefits are that portable structures such as this have the capacity to solve problems which conventional buildings simply cannot. Some of the experience gained in projects of this nature may also be of value in the creation of permanent buildings, either in technical matters or in design processes. One example might be the use of hydraulics, which could be utilised to increase flexibility and adaptability in use by the movement of discrete elements in a building which is otherwise static. The awareness of alternative ways of making buildings, introduced by the experience of cooperating with contractors and manufacturers not usually involved in the building industry, may also be valuable, for example, stage and theatre contractors who are used to much more compressed programmes and flexible working methods.

Because of their unusual nature, the design process is more intensive for portable buildings. The dedicated attention to detail so important in their design, should of course be applied to any problem. However, in conventional construction projects, so many standard approaches are available that the extra effort required to investigate the possibility of a detail improvement is sometimes missed.

Volvo Car Mobile Marketing Units

In the early 1990s the Swedish car manufacturer, Volvo, undertook a review of their company image – their cars were universally perceived as reliable and safe, if dull, and the company deduced that if they were to retain a competitive edge into the next millennium they would have to introduce to their customers the idea that the Volvo was not just a family car, but a family car with extra comfort, excitement and style. One aspect of the company's image revamp was the introduction of a new unified corporate image for all their showrooms using steel, etched glass and natural birch details – a classic, cool, Scandinavian design style. Another aspect of this change in marketing emphasis was the involvement of the company in motor sport, which is now used not only as a testing ground for design development but also as a promotional tool. Spectators at motor sport events are invariably car purchasers and so, to make the most of their sponsorship activities, companies need to establish a marketing presence at each race. Volvo UK had purchased one of the Apicella-designed TSB pavilions to provide a venue at race events and the experience gained proved that the creation of a dedicated facility would be worth while. In 1996 they appointed the Russell Organisation as project managers who helped them to compile a shortlist of three design practices who were invited to pitch for the work to design and manufacture a new mobile building specially for their marketing department. Apicella prepared a detailed scenario for this presentation that not only showed the form and character of their proposed structure but also explored its construction, materials, deployment, and logistical

Fig. 6.15 The Volvo Car Marketing 'pavilion' in use as a reception/entrance to a commercial rented structure.

strategy. Unlike the TSB and the HKTA pavilions, the aim of the Volvo UK project was not just to create a single stand-alone object but to make a family of separate units with the same unified image which could be deployed separately or together depending on the size and importance of the event. In this situation, operational simplicity and flexibility were paramount. With this in mind, Apicella created the concept of a discrete curvilinear building made of materials visually similar to those used in the new showroom (Fig. 6.15). Though this structure was designed to be built on different size truck beds, once again his objective was to give the appearance of a high-quality modern building rather than a temporary trailer.

Three different types of unit have been built (Fig. 6.16). The smallest is a promotional facility which functions as an office and hospitality venue

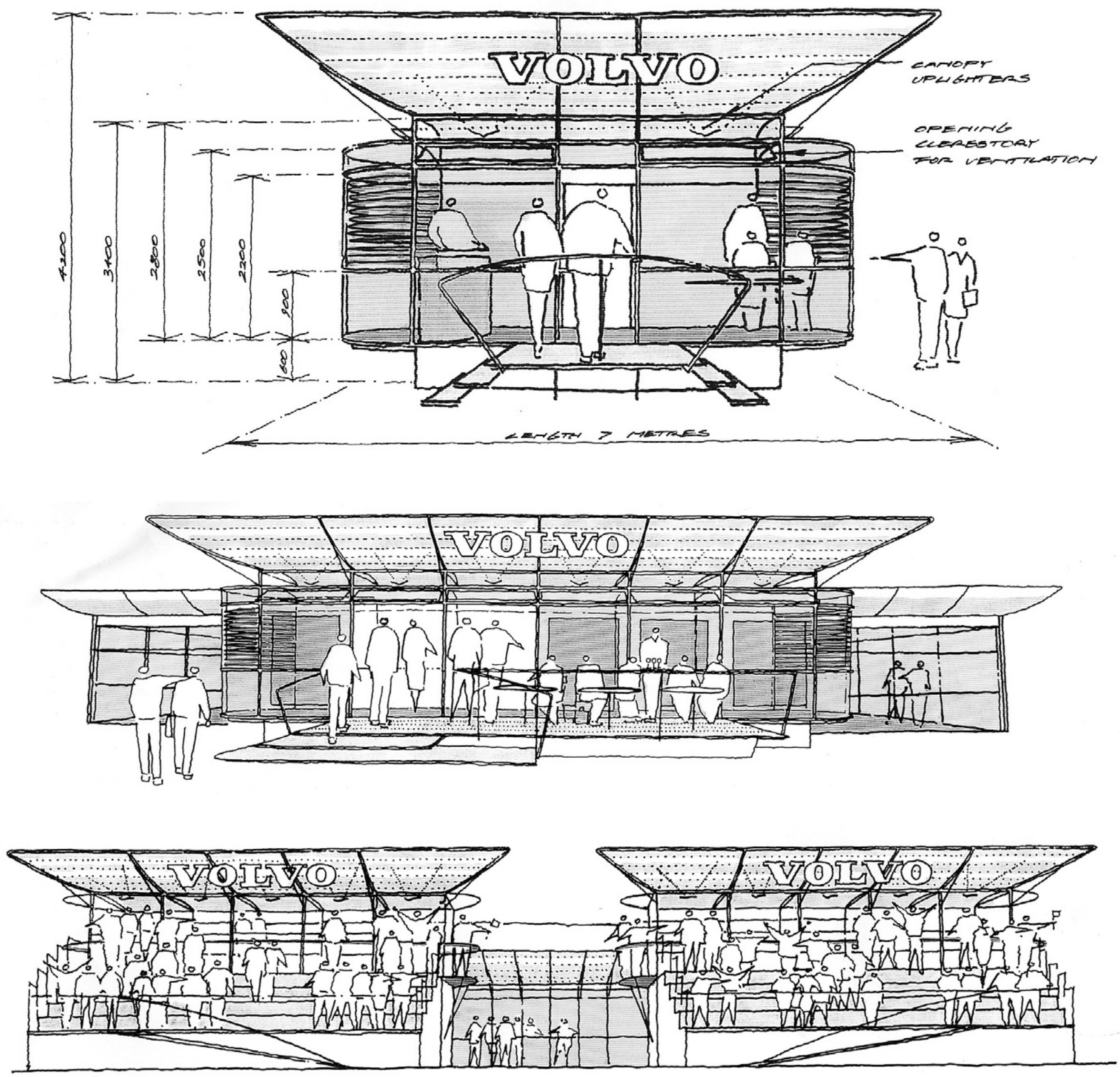


Fig. 6.16 The Volvo units top to bottom: the promotional unit, the 'pavilion', and a concept proposal for further units which can be used as a viewing and hospitality facility.

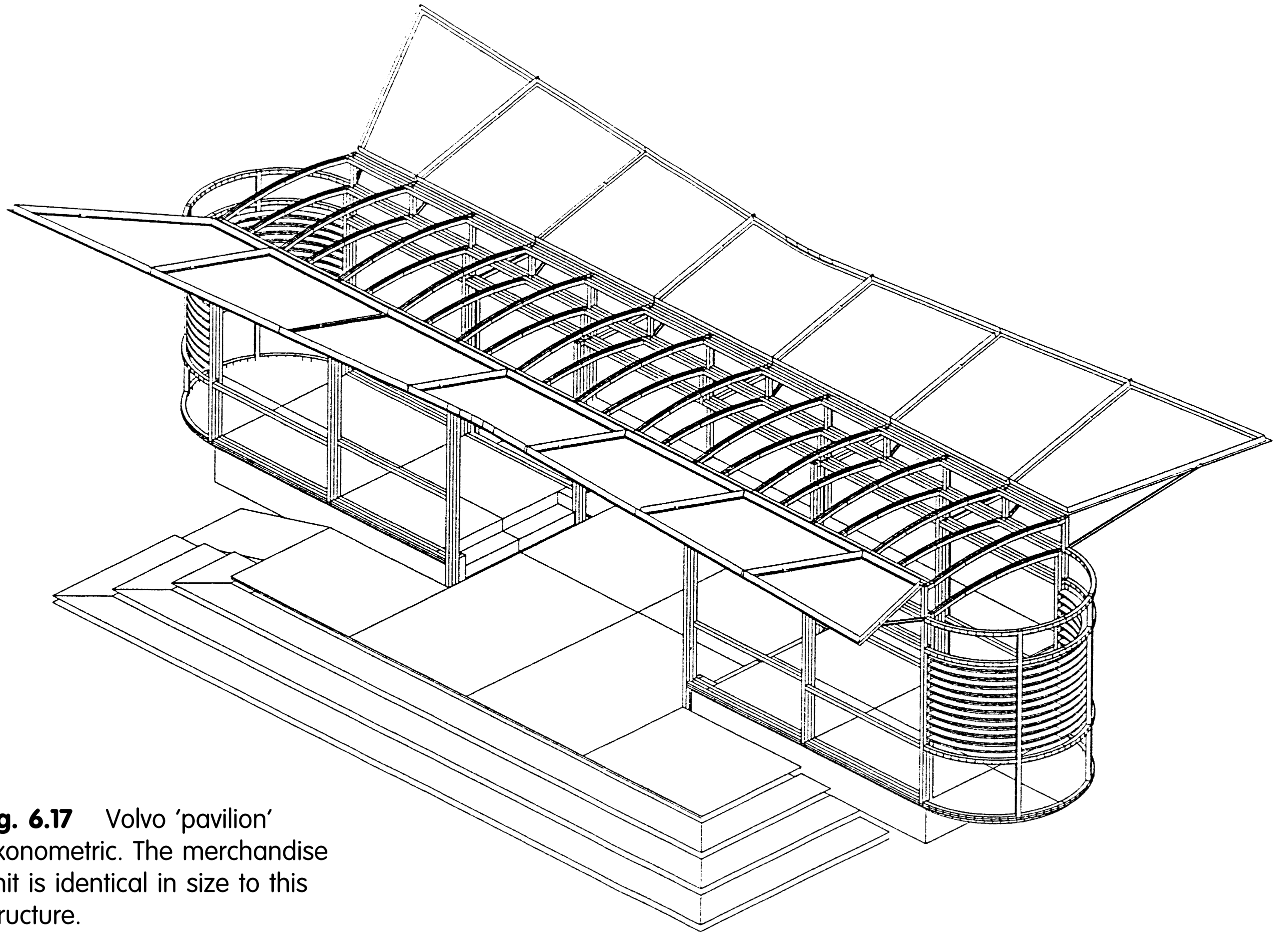


Fig. 6.17 Volvo 'pavilion' axonometric. The merchandise unit is identical in size to this structure.

for small groups – it is based on a flat-bed trailer capable of being towed by a large van. The other two structures are built on a large articulated lorry trailer. The merchandise unit is a stand-alone shop selling Volvo racing tie-in products such as clothing, books, and souvenirs (Fig. 6.17). The pavilion is a multi-function facility which can either be used as an independent hospitality venue or as the reception entrance to a much larger rented commercial marquee structure – effectively grafting a corporate image onto what is mostly an anonymous standard facility.

All the units share the same basic construction, a silver-painted, 50 mm square hollow steel section structural framework that supports a proprietary aluminium curtain walling system surrounding clear and etched polycarbonate panels. The parallel roof sections consist of curved polycarbonate panels with opaque, glass reinforced plastic sections used at the double-curved ends. A number of fold-out and fold-down elements are added to the basic form (Figs 6.18–6.20). Every unit has a canopy over the entrance which is hinged to the roof edge and folded down alongside the walls during transportation. All also have either entrance steps or platforms made from steel, though these vary in complexity depending on the unit's function. The promotional unit has a set of steps which are placed into position manually, the merchandise unit a series of fold-down floors which add 60% additional floor area, and the pavilion has a hydraulically operated fold-out floor which is used to make a covered walkway to the larger marquee-type space at the rear. Once fully erected, a silver-coloured GRP panel skirt is placed around each unit's base, concealing the truck bed structure and wheels. Every unit has an on-board generator and, where necessary, plumbing. The team received the commission in October 1996, construction began in January 1997, and the pavilions were ready for use by the beginning of April that year.

These units travel to a large number of events each year (250 in their first six months) but stay at each venue for only a limited amount of time,

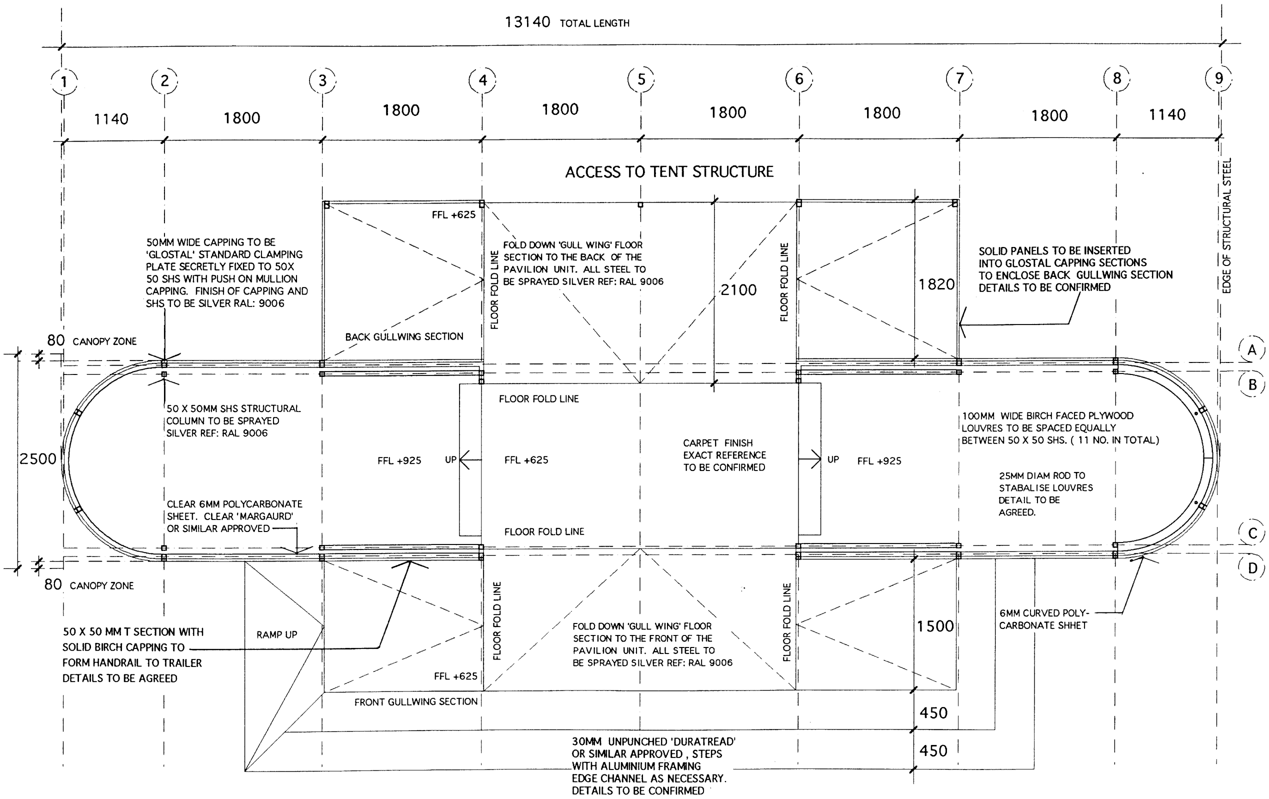


Fig. 6.18 Volvo 'pavilion' plan.

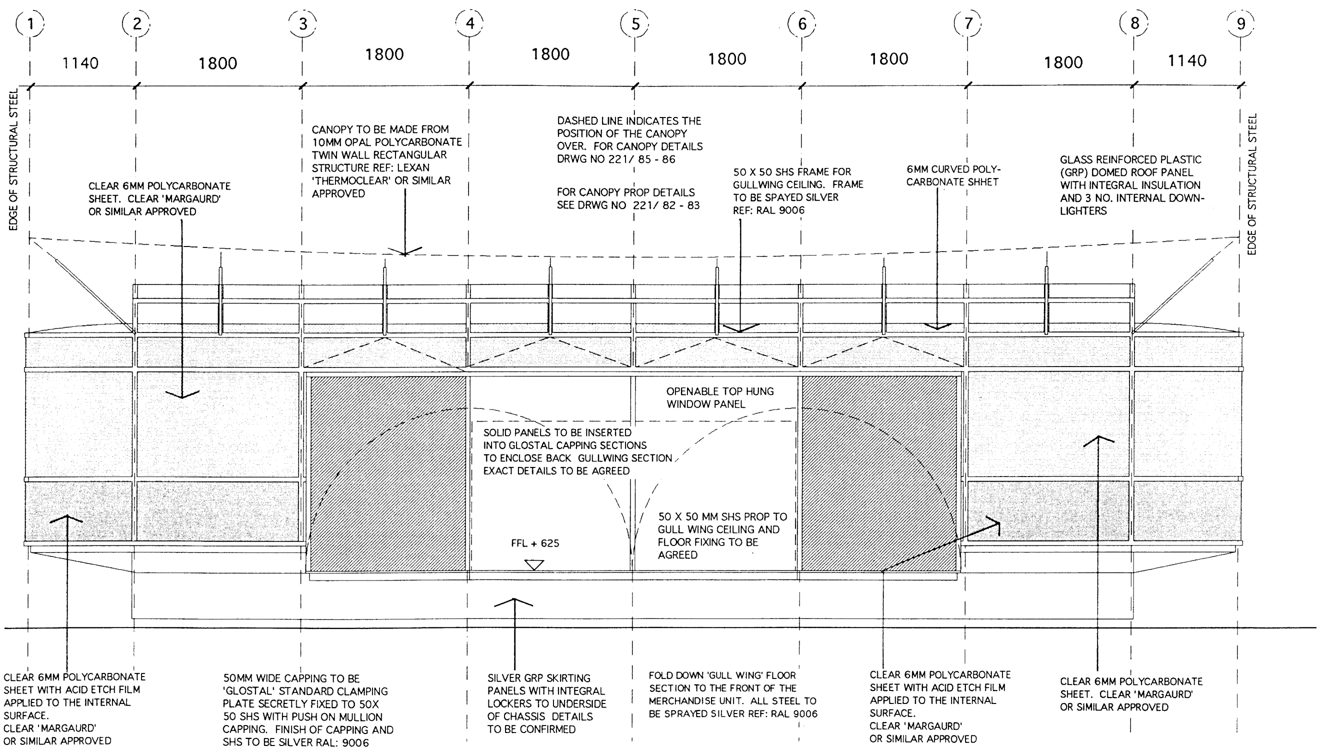
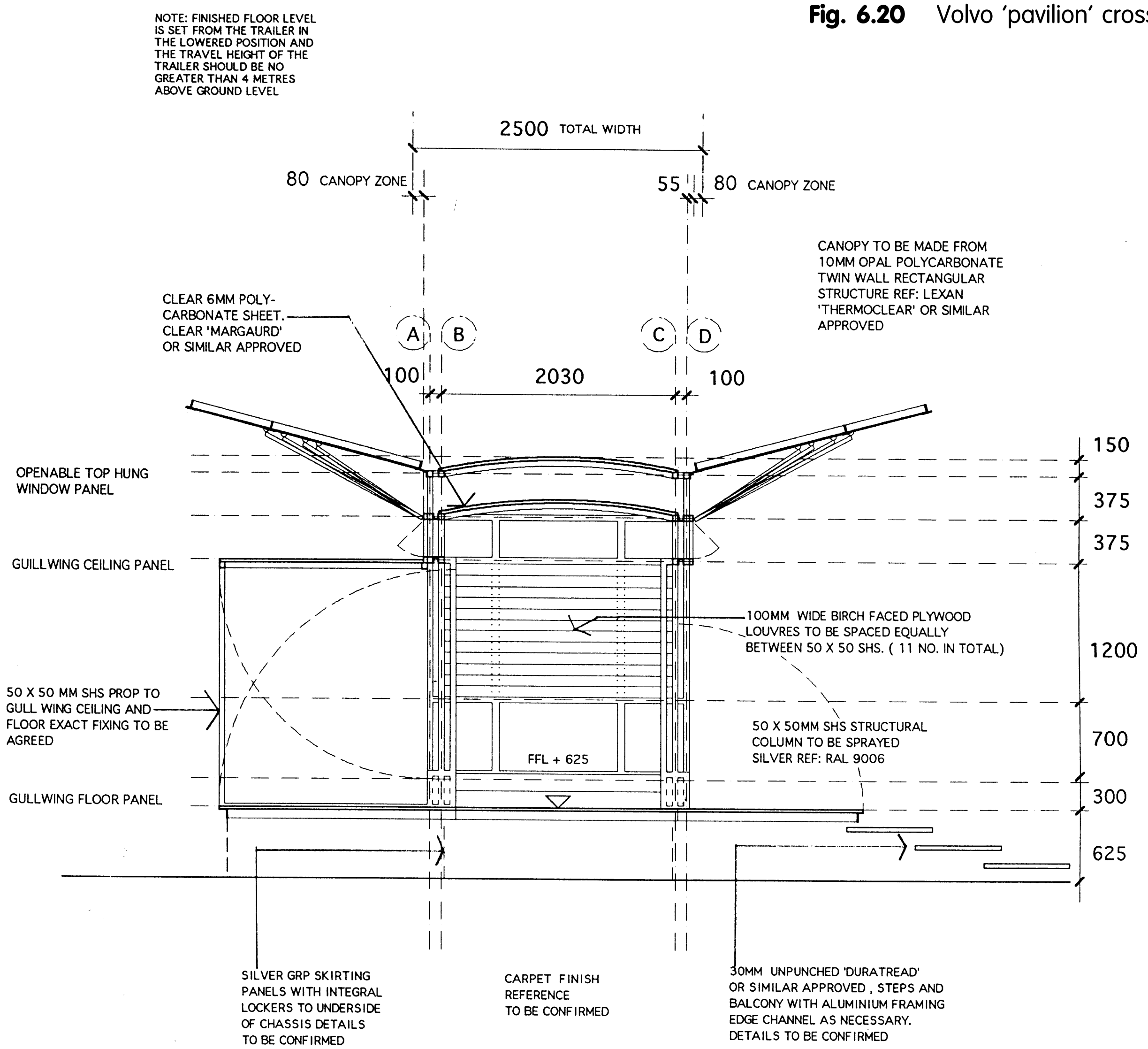


Fig. 6.19 Volvo 'pavilion' rear elevation.

Fig. 6.20 Volvo 'pavilion' cross-section



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usually two to three days. Most of the set-up procedures are done by hand and they have been designed to be completed in two to three hours by just one operative, though usually two people accompany each facility on the road. When in transit each unit is covered with a tailored PVC cover. The Russell Organisation not only built the units but also manage them during the race season for Volvo UK, providing transportation and set-up services for all the sites, which consist mostly of fields adjacent to race tracks. This arrangement is typical of facilities such as this which are purchased not on the basis of the object which has been made but on the events that they support. This project spans the gap between vehicle design and architecture. The facility derives its image from the design of static showroom structures but has a movable 'foundation' in the form of a standard truck bed. More significantly it appropriates the modern stylish efficiency of the car manufacturer's products to communicate this image to the customer.

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Bristol Development Corporation Marketing Centre, Bristol

Date: **1992**
Client: **Bristol Development Corporation**
Architect: **Alec French Partnership, Bristol, UK:** David Mellor, Nigel Widdup, Ian Smith
Engineer: **Whitby and Bird, Bath, UK:** Mark Lovell
Consultants: Interior Design: **Hop Design**
Exhibition Design: **Proctor and Stevenson**
Contractor: **Pearce Construction, Bristol, UK**
Steelwork: **Tubemasters, York, UK**
Cost: **£350,000**

In recent years a common response to urban regeneration implementation has been to create a special organisation dedicated to the redevelopment of a specific area. As an aid in focusing the key objectives of its task and bringing its work to the attention of the public, several of these organisations have chosen to create an on-site temporary visitors' centre that represents a physical sign of investment and change. Such a building can also bring a brief flurry of activity that generates valuable publicity. The Bristol Development Corporation's mobile marketing and exhibition centre was designed by the Alec French Partnership in response to a limited national architectural competition. One of the other competing entries was designed by Alsop, Lyall and Störmer, whose charismatic Cardiff Bay Visitors' Centre possessed a similar purpose but a different logistical strategy in that it was intended to be temporary rather than transportable, and its capacity for movement was strictly limited by its construction. This is not the case with the Bristol building where portability was not only an important part of the design brief but also became a main generator in the development of the structural concept and construction detailing.

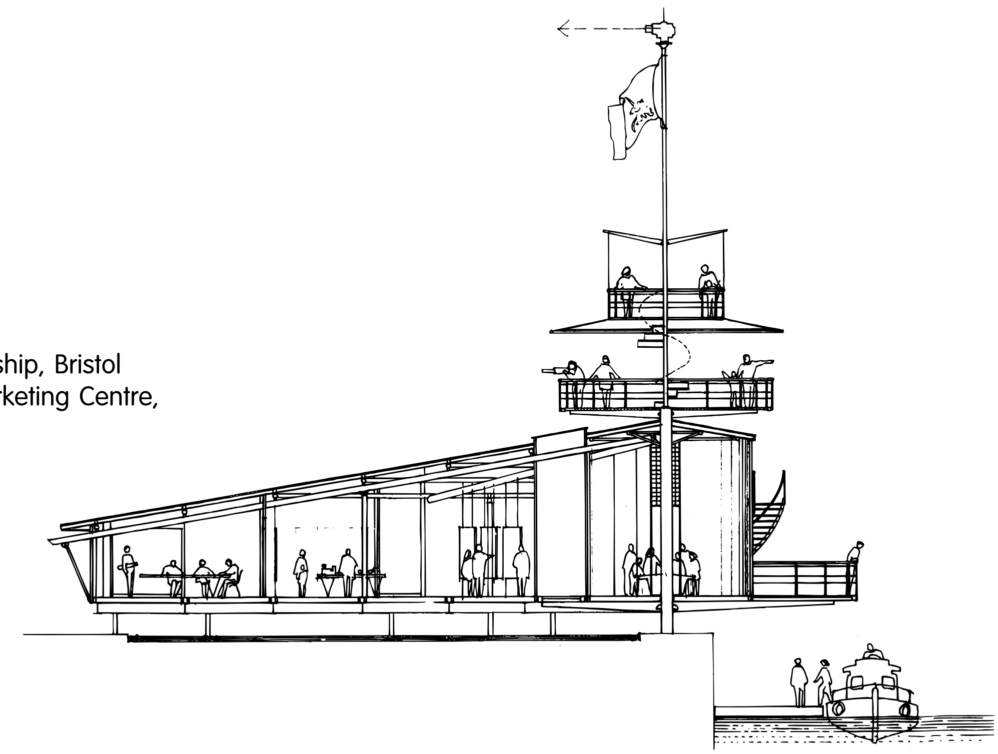

Fig. 7.1 Alec French Partnership, Bristol Development Corporation Marketing Centre, 1992, section.

The Bristol Development Corporation required a building with a bold presence that would attract attention to its marketing function. It would need to represent the potential for commercial regeneration in a part of the city that had suffered from long-term lack of investment and also communicate the start of a new era in the area's development. The building should also convey the Corporation's commitment to high-quality modern design by presenting a new and dynamic image. Portability was an important factor because it was envisaged that the building would move every two to three years to new parts of the development area as individual sites began to be redeveloped. Short-term functional flexibility was significant as the building was expected to accommodate exhibitions and presentations to a wide range of visitors including school children, businessmen, politicians and investors. The long-term strategy is that the building will eventually be permanently relocated on a yet to be decided site in a community-related function – an ability to adapt to a future unknown role was therefore important.

The initial site for the building was to be adjacent to the River Avon, close to Temple Meads Railway Station. Though at a convenient entry point to the development area, this site is at a relatively low level and possesses limited views both to and from the building. The designers realised that if the building was to have a significant presence, both for visitors approaching the building and also for views out to the area to be developed, it would require a significant vertical element incorporated into its form. The site of the Cardiff Bay Visitors' Centre with its dramatic position and wide views across the bay could hardly be more different.

The main element of the Bristol building consists of a single, 27 metre high vertical mast from which all the secondary structural elements radiate. The mast concept can be related to nautical imagery, which is dynamic and kinetic, and also historically linked to the site on the River Avon in the port city of Bristol (Figs. 7.1–7.2). However, it is the structural flexibility of the mast strategy that was more important to the designers, in that masts,

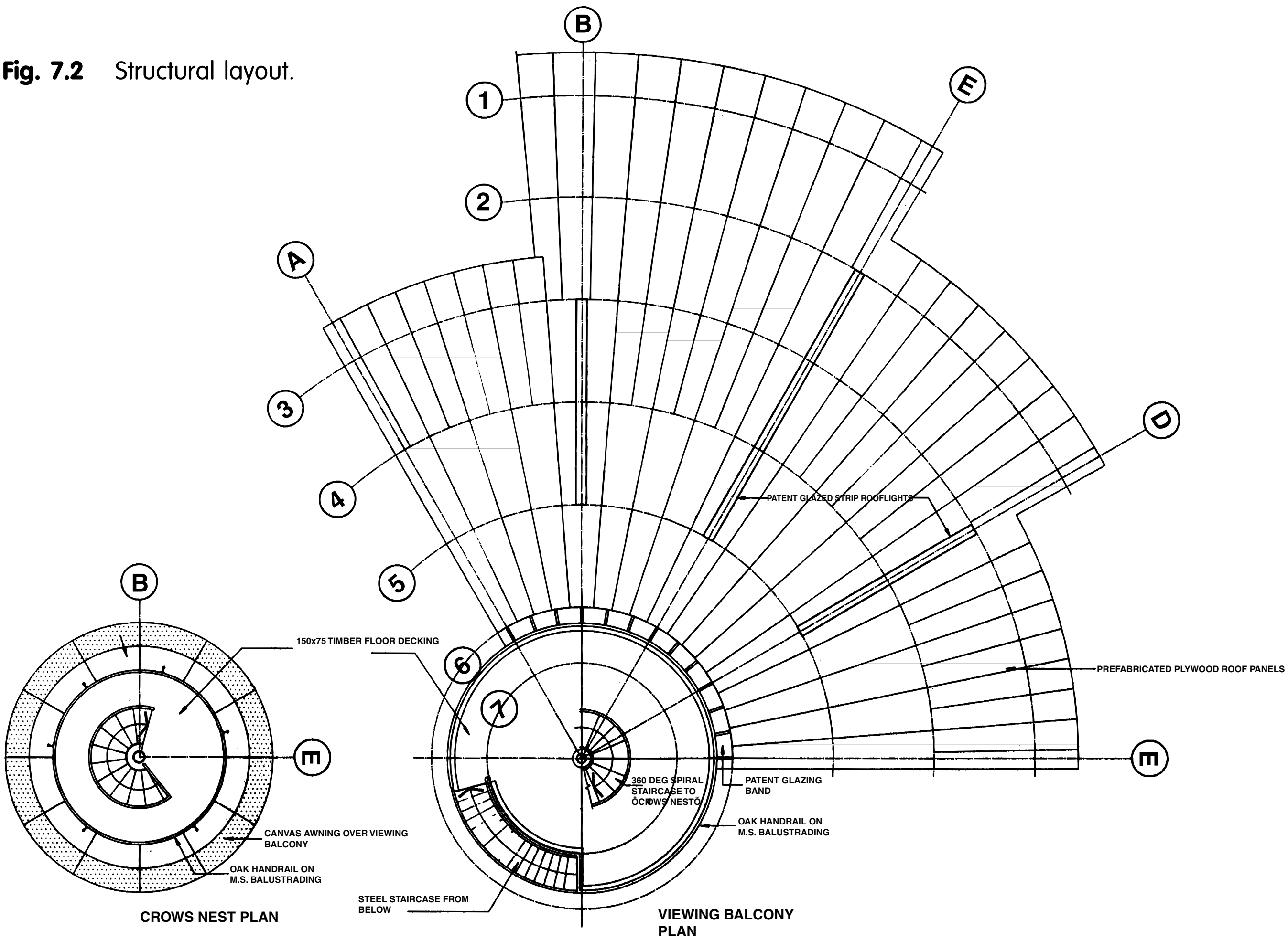

Fig. 7.2 Structural layout.

spars and rigging provide a lightweight structural system which is also flexible and demountable. The designers, architect David Mellor and engineer Mark Lovell, also describe the mast element as like an artificial Christmas tree which has branches that can be pressed up against the main trunk for storage (Fig. 7.3). This concept is important for the portability of the building as it means that the entire main structure can be transported on a single lorry. The main foundations that support the mast and intermediate columns for the roof are the most substantial in situ preparations for the building. Most of the floor area rests on simple 300 mm square concrete pads. After foundations were prepared, the mast element (made in the factory by specialist steel fabricators Tubemasters), was delivered to site and set into position by crane (Figs 7.6–7.8). All the horizontal structural elements of the ground floor, the roof, and the two upper external floors were then swung down into place. The hinged joints between mast and horizontal beams are clearly visible in the completed building and define this dynamic feature of the construction (Fig. 7.4). The five, 19.5 metres long primary rafters have intermediate columns fixed with a pin-joint which allows them to be swung down into position as the rafters are lowered. The supports for the external upper level floors are cantilevered beams, six at the first level and five above. Access to the upper floors is by a circular staircase that encircles the mast and is fixed into factory-made brackets. Once all these elements are assembled on site, a dry-fixed secondary framework is added to brace the main structure and support the cladding. The structure flexes more in use than a comparable permanent fixed structure, and the wall and floor panels have

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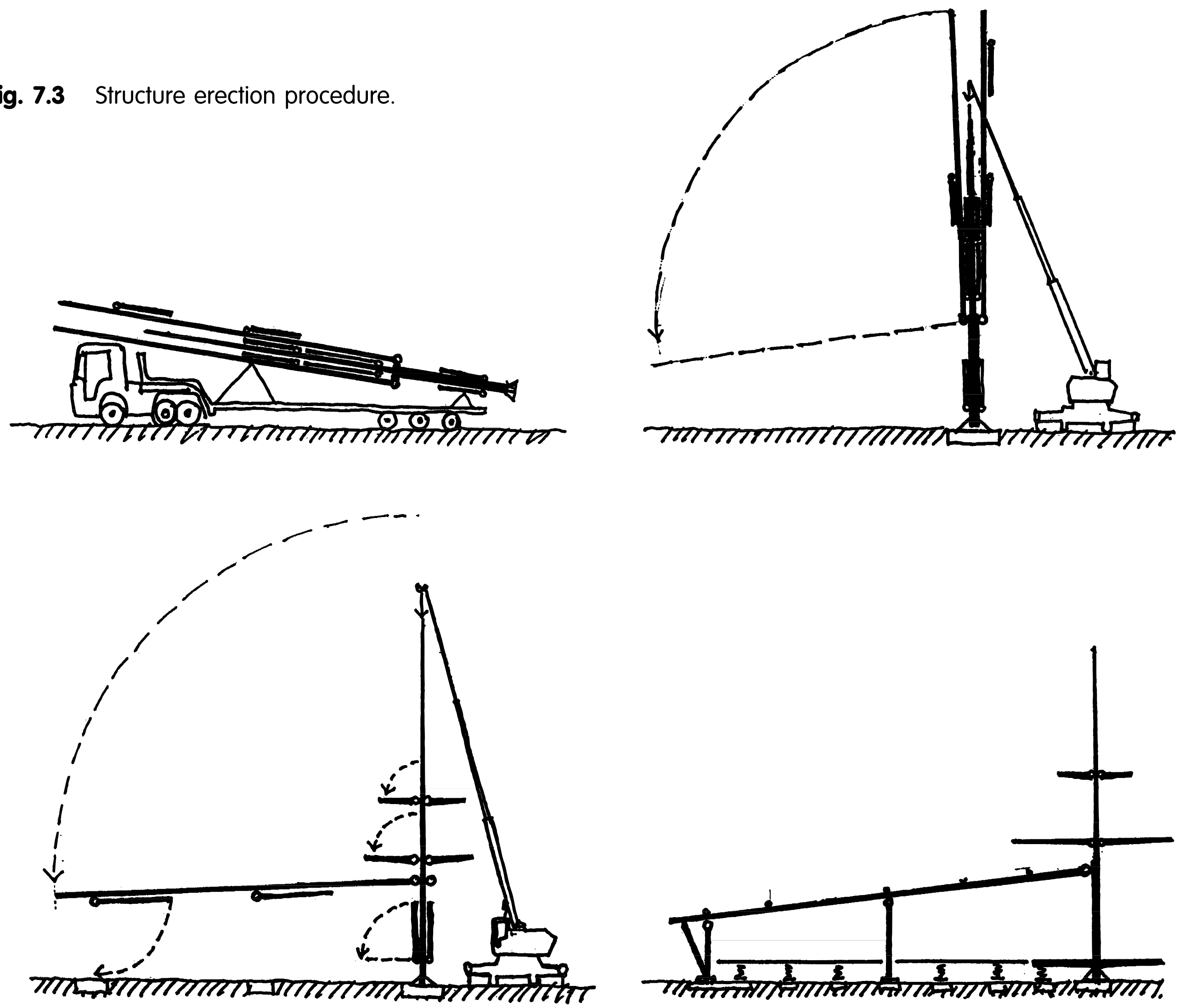
Fig. 7.3 Structure erection procedure.



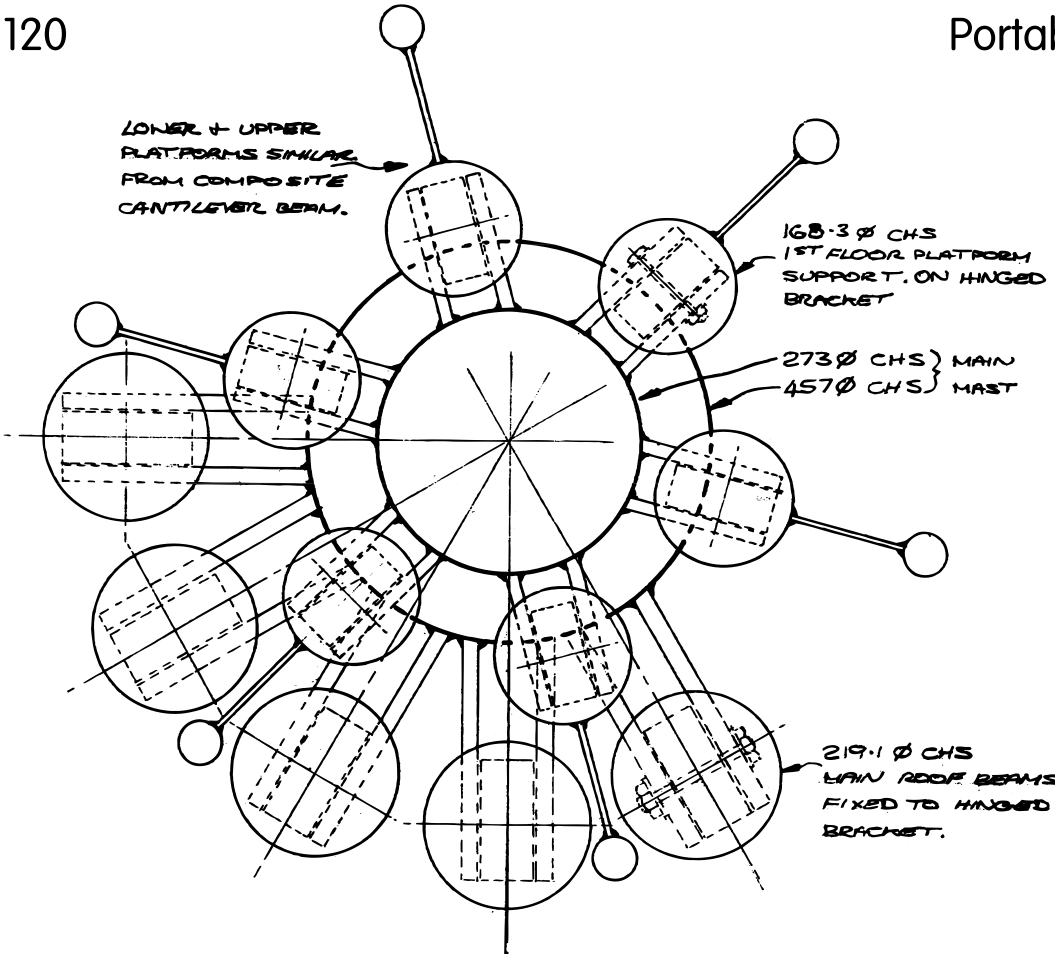


Fig. 7.4 Horizontal section through mast showing the supports for floor and roof beams and observation platforms.

consequently been carefully detailed to allow for movement. A modular system using proprietary 70 mm thick composite steel skin panels hung from the purlins has sliding joints at floor and roof level. The panels are fixed in place by a press-fitted neoprene gasket in vertical joints. The floor and roof system was specifically designed for the building and uses a marine ply sandwich panel that can be removed in whole sections when the building is dismantled.

The most dramatic elements of the building are the external upper floors which are primarily used as observation platforms – a hardwood deck reinforces their nautical character. At the lowest level the mast is surrounded by an internal space from which entry to the external deck can be gained. The first floor deck is partly protected from sun and rain by framed canvas panels. The circular staircase leads to the next level which is suspended by rods from the cantilevered beams above. Besides conventional viewing from this platform, part of the

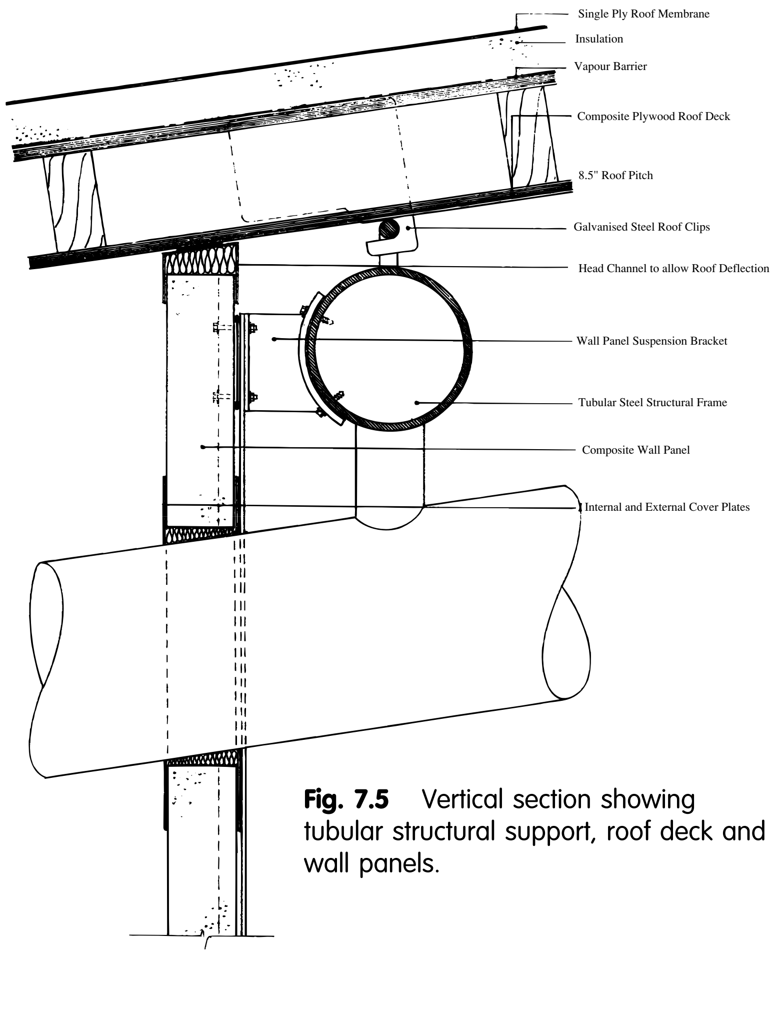


Fig. 7.5 Vertical section showing tubular structural support, roof deck and wall panels.

Fig. 7.6 Deployment of the mast.

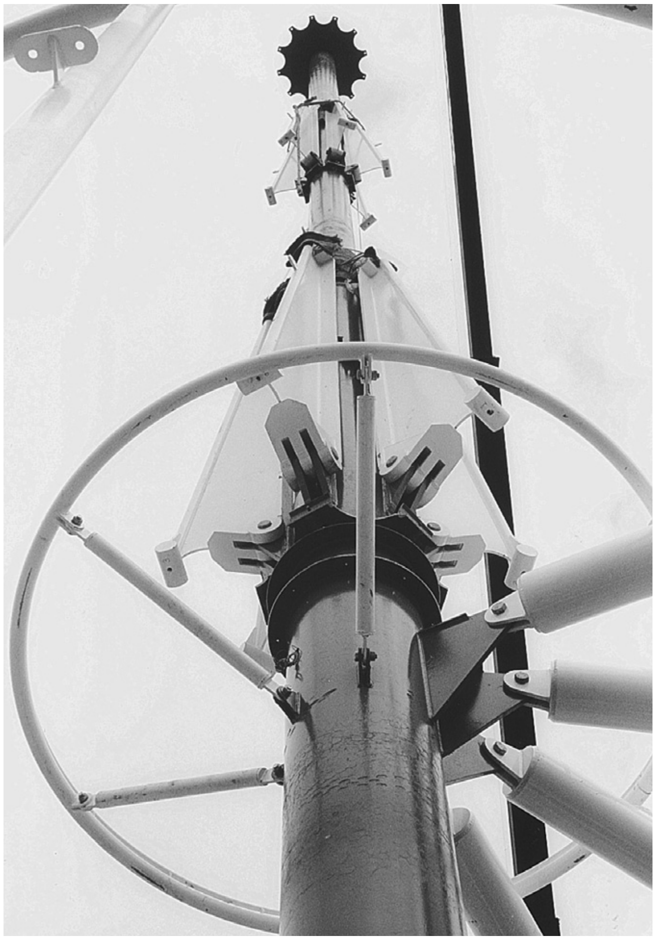


Fig. 7.7 View from the base of the mast with the main horizontal roof beams deployed. The platform beams are still in their travelling position against the mast.

original concept was that a video camera would be mounted on top of the mast which could be controlled by visitors in the drum space below. Images from this could be used to relate actual real-time views from the building to computer-generated images of the site as it would appear in the future.

All the main components of the building were factory manufactured, assembled on site and are capable of disassembly when necessary. Only the site foundations and the single membrane roof are disposable and even the roof could be slit at the structural panel joints and taped over at the new site (though the designers believe that the risk of rain penetration is not worth the £6000 cost of a new, single membrane roof finish). The lightweight nature of the building is emphasised by the way it rests poised on slender legs above a temporary shallow artificial lake. The use of water in this way was also intended to indicate the client's intention to encourage high-quality landscaping across the entire site, using water as a main linking element.

Entrance to the building is by metal ramps that gradually elevate you to the main 200 square metre floor level that, in the building's first manifestation, contains exhibition and meeting spaces, toilets and a small kitchen. A similar ramp leads down from the dockside to a floating pontoon from which water taxis and pleasure boats depart. The entire building, apart from the blue-coloured main mast and timber decking, is finished in white, softened internally by low-voltage spotlights. Though there are undoubted connotations with the whiteness of maritime structures the architectural form expresses its modular cladding system rather than the organic continuous shell form of a boat. Whatever superficial associations come to mind, it is the exposed use of structural elements and unusual sculptural form that shapes the building's image and defines its presence as an architectural object (Fig. 7.9).

The Bristol Development Corporation Marketing Centre was built during a rapid construction programme of seventeen weeks and completed in August 1992 for a sum of £350,000. The design features which were introduced in order to achieve the portability requirements of the brief have also proved valuable in successfully meeting the deadlines of a relatively short contract period. The structural mast strategy and modular construction minimised the extent and cost of site preparation, reduced site operations to a minimum, and meant that much of the work could be carried out in the factory to higher specification. The building has reached the end of its original period of deployment, however, it has continued in position on its original site. This is partly because the original site selection was good in terms of location, but also the response to the site's problems was effectively dealt with in the form of the building. The building is also in constant use and its removal from operation for even the few weeks it would take to relocate is seen by the client as a considerable inconvenience.

The architect believes that the unusual nature of this building was more acceptable to the client because it was not intended to be permanent, and that it has been a definite advantage in attracting visitors (Fig. 7.9). Despite its extended location on the same site the portability aspect of the design has still proven valid as it led to associated constructional advantages, particularly in helping

Fig. 7.8
The structure partially erected.

Fig. 7.9
The building is sited close to the water's edge. The structure is expressed externally both at the mast and in the roof supports.

to meet a compressed programme. It is unlikely that such a dramatic architectural image would have resulted without portability being a condition of the brief. The temporary nature of the building's siting meant that it could be more radical in appearance and experimental in form and deployment than would otherwise have been considered by either client or regulating local government authorities. In addition to being capable of reuse in different locations and for different functions, the design brief requirement for portability has proven to be a factor that has positively affected the construction strategy and architectural image in ways that would be of benefit in any building project, portable or permanent.

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IGUS Factory, Porz Lind, Cologne, Germany

Date: **1990–2001**
Client: **IGUS GmbH, Cologne, Germany**
Architect: **Nicholas Grimshaw and Partners (NGP), London, UK:** Nicholas Grimshaw, Mark Bryden
Engineer: **Whitby and Bird, London, UK**
Consultants: **Buro Weiss, Aachen, Germany:** Michael Weiss
Contractor: **Trafalgar House Construction Management, London, UK and Walter Bau-Ag, Augsburg, Germany**
Cost: **£12 million for Phase 1–5**

Nicholas Grimshaw and Partners' IGUS GmbH factory in Cologne, Germany, is clearly not a building which is intended to be portable, though there are discrete purpose-designed portable building elements within it. However, it presents such a unique example of flexibility in building construction that its inclusion with these studies is not out of place. Virtually every part of the building has been designed to be relocatable without specialist help and though the main structural support is static, all cladding, fixtures and fittings are of demountable construction that not only have relevance to the design of flexible industrial buildings but also to architecture that may be moved in its entirety.

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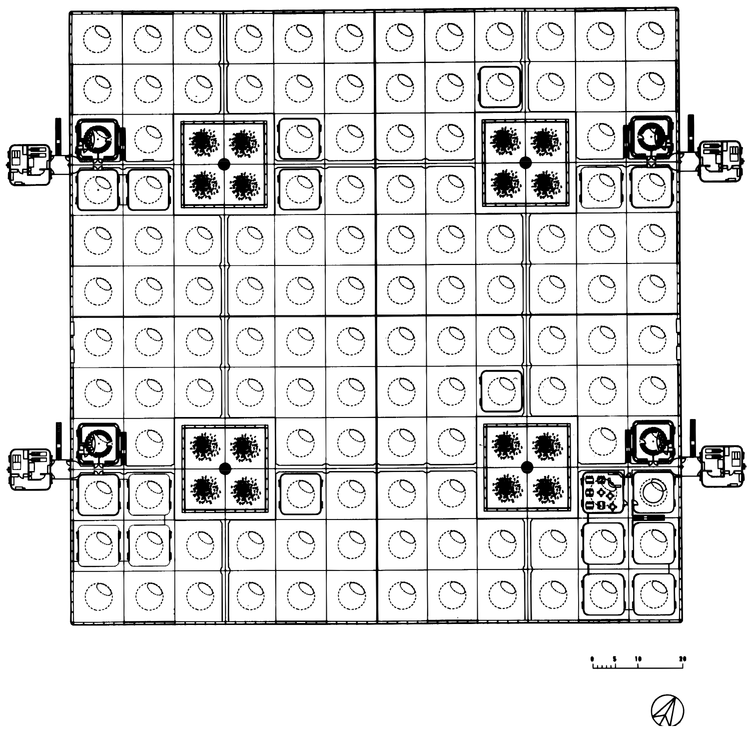


Fig. 8.1 Nicholas Grimshaw and Partners, IGUS factory, Cologne, 1992–95. Floor plan of the proposed final development. The four masts are located in the centre of the internal garden courtyards. The external pods are located in fixed positions – internal pods can be relocated in any position.

IGUS is a family-run business based in Cologne that makes injection moulding tools supplying machine parts for industry. Self-made man Günter Blase founded the company in 1964 and operates its production side. His two sons, who have business school training, now administer the business, and Blase's wife Margaret is the company accountant. The products that the company make challenge conventional use of plastics and have been used to develop new markets in areas that previously utilised metal components. From the beginning Blase developed a very flexible approach in the operation of his business, dramatically changing the manufacturing operating systems within his factory to streamline the process for making the widely different tools that his clients required. In the 1980s the company occupied a three-storey masonry building in Cologne which not only had insufficient space for their operations but was also physically restricting the production process. A symptom of this was the fact that the car park had to be emptied so that materials deliveries could be made. Despite this restrictive physical environment, the changes in production layout from job to job were so essential that brick walls were demolished and rebuilt in order to accommodate the operational changes.

Though a production engineer, Blase is interested in architectural design and understands that the environment for any activity can be detrimental or advantageous to operational efficiency. He had considered adopting a standard approach to solving the factory's accommodation problem, either by moving into a speculatively built factory or commissioning a design-build package. However, he was aware that though these would be quick solutions, the long-term result would be compromised as the ultimate flexibility the business required would not be provided. In May 1990 IGUS acquired a plot of land outside Cologne with planning permission for light industrial use and decided to build a new factory. Blase set out to find the right sort of architect who could design the flexible building type he envisioned, which would be built in phases as funds allowed. He visited the USA, Germany and Italy as well as the United Kingdom before seeing Grimshaw's design for the Herman Miller warehouse in Chippenham. Herman Miller produced high-quality office furniture designed on modular principles which enabled it to be rearranged into many different patterns associated with different tasks. The warehouse which Grimshaw designed for them in 1982 utilised a similar system in the building's cladding that allowed panels to be moved depending on changing functional requirements. The building was also situated next to the main London to Bristol railway line and created a highly visible, crisp modern image for thousands of potential customers. Blase identified these features of the building as synonymous with the requirements for his own factory and went to Grimshaw's London office where he walked in off the street without an appointment and asked to meet the architect so that he could offer him the job of designing his factory. In the brief for a limited competition between Grimshaw and a local German architect, Blase encouraged the creation of a prominent, high-profile example of exciting architectural design that would complement his company's image. This led to an unqualified acceptance of Grimshaw's proposals which were described by the client as 'perfect'.

Nicholas Grimshaw and job architect Mark Bryden visited the existing IGUS works for a three-day period and spent two days examining the way the factory worked and preparing a brief. On the third day they presented it to their clients who responded and contributed to its form and content. Though the Blase family are clearly in control (the operation of IGUS has been described as an enlightened autocracy) the IGUS company is run in a uniquely equitable manner. One manifestation of this is that there are no special facilities for administrative staff – factory, office and supervisory workers all share the same facilities. Furniture is standardised throughout the offices irrespective of the individual's seniority. Meeting rooms all have glass walls. When walking through the factory with Blase, the company's founder appeared to know the name of every worker and the details of his task.

At an early meeting Bryden dubbed the method of operation of the company as the 'solar system', a term which has since been adopted within IGUS. At the centre of the company's operations (in the 'Sun' position) is the client's organisation, and around this orbit the different parts of the company – accounts, manufacturing, dispatch, etc. The workers orbit around each of their departments. Individuals within the company can shift from team to team dependent on the requirements of a particular project. The client has direct access to these parts of the company and they have direct access to him. This means that the client can liaise directly with those manufacturing, shipping, or costing his product without having to go through middle management. The individual departments of IGUS therefore have direct responsibility in the success and profitability of their business. The

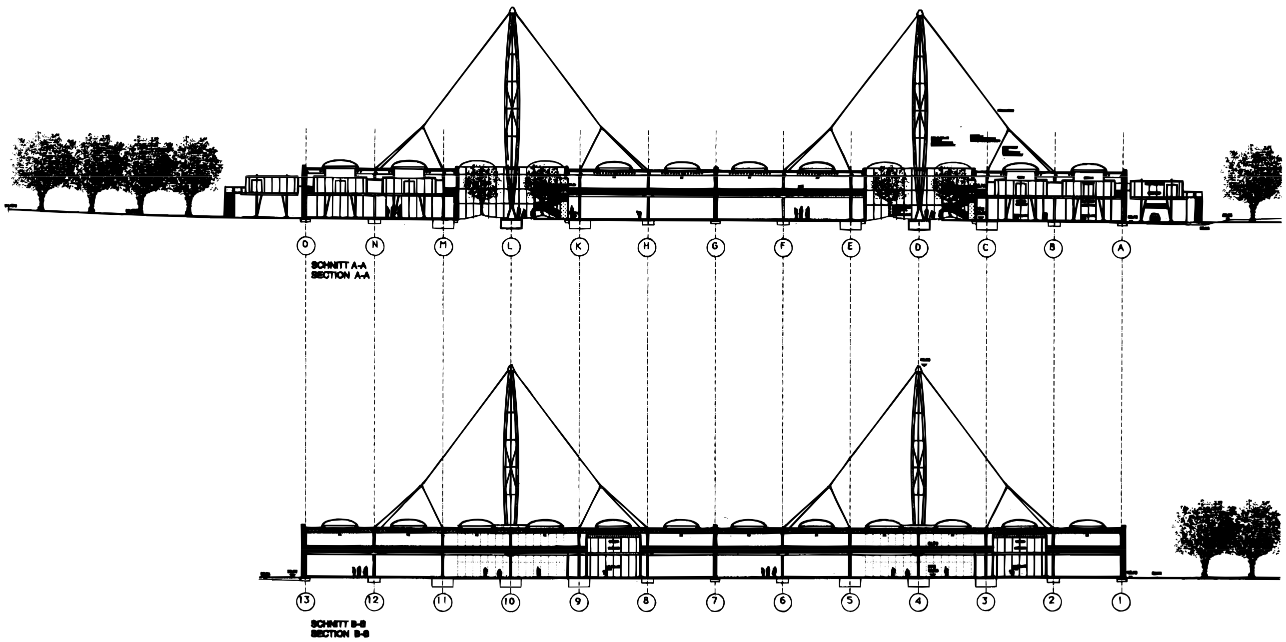


Fig. 8.2 IGUS factory. Top: cross-section through courtyards.

management team, including Blase himself, fits into this pattern as comets who pass through the basic system visiting each of the departments as required. This organisational method allows flexibility of operation combined with direct responsibility and reaction to client requirements.

Though the client took great care in the selection of his architect, Nicholas Grimshaw and Partners felt that they were still under pressure to perform effectively, and had they not responded imaginatively to the issues that Blase had identified, they would have been dropped. As a designer and engineer, Blase dealt with innovation in his daily activities and demanded innovative thinking from his consultants.

The design team developed the concept of a building that would not only be flexible in detail, allowing the relocation of elements from place to place within the building framework, but also in form in that the phased construction would consist of a series of modular spaces and enclosures adaptable to different uses and erection in different sequences. The ultimate size of the building, divided into four, 68-metre wide square bays, will eventually form a 24,620 square metre building, though this may be built in up to seven separate phases (Fig. 8.1).

This basic structural pattern is of a 40-metre high pylon which provides the main structure for the suspended roof allowing column-free spans of up to 33 metres. The tall bright yellow structural element sets the building apart from other factories as it is an easily recognisable external feature that conveys the clear span nature of the space it supports. It was a popular design feature of the clients, who perceived it as a clearly visible symbol for the building, recognisable in published photographs, but also from the adjacent motorway and aircraft on the flight path to Cologne Airport. The pylon base, which would provide a fixed element in the structural grid, is set into an 18-metre square, open landscaped courtyard which has a glazed elevation to the factory floor (Fig. 8.2). In the completed building there are four of these courtyards, each landscaped to reflect a different season. These were seen by the architects as a reflection of the natural pattern of the company's organisation that also provided the practical benefit of visual relief for workers at the centre of the building. The flexibility designed into the phasing process proved of value almost immediately. Only a small initial phase was originally planned, with IGUS retaining their existing premises elsewhere, however, their business expanded quicker than expected and the first phase became much larger and eventually expanded to a £8.5 million project of 8900 square metres which was completed in December 1992. The flexibility in form and detail created for the benefit of future additions and alterations allowed changes to be made during the first

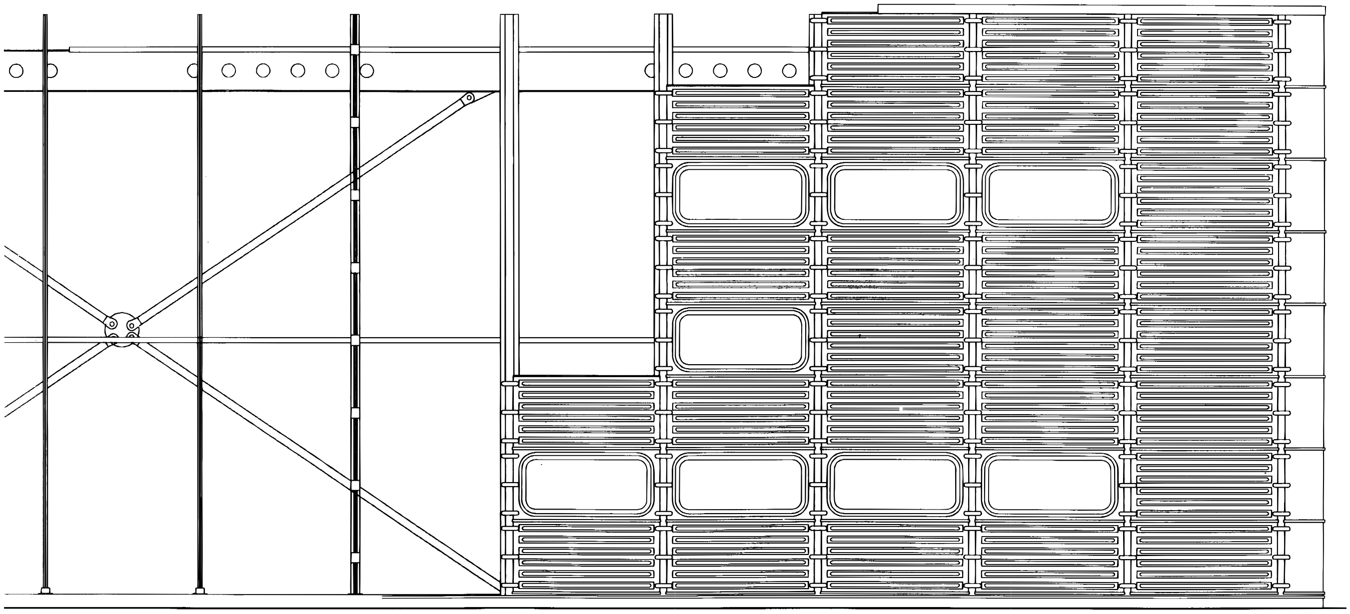
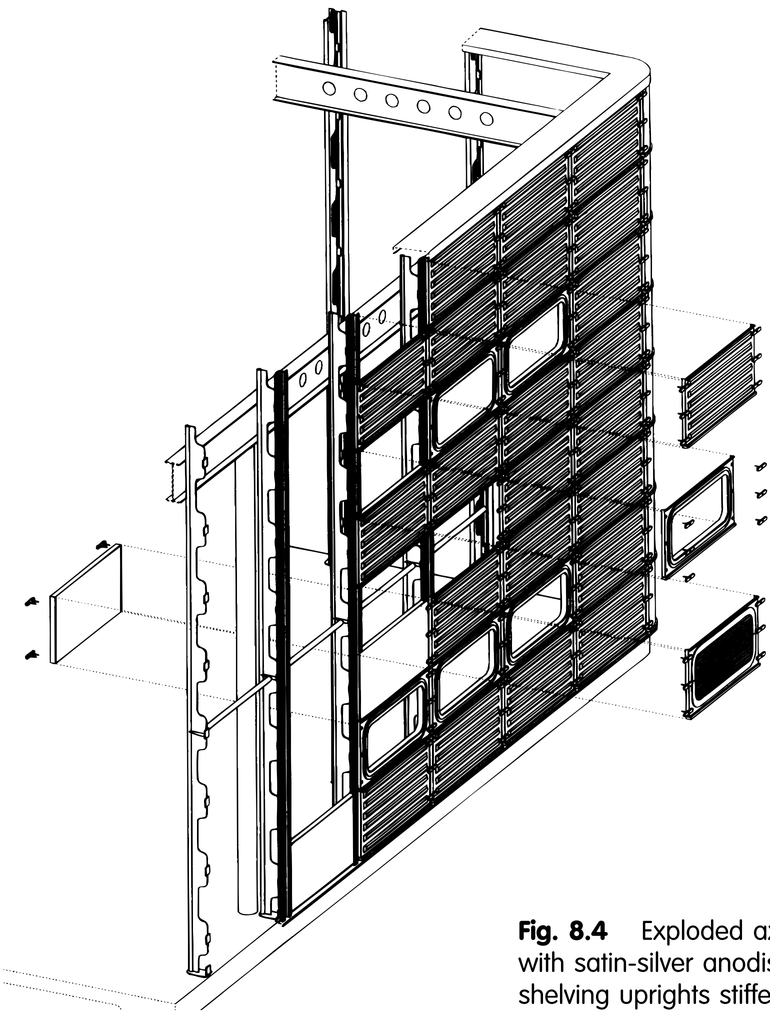


Fig. 8.3 Detailed elevation with cladding partially omitted to show structure.



major building phase with relatively insignificant interruptions to the programme. Subsequent phases (2–5) have concentrated on the provision of additional space up to a total of 18,850 m^2.

The clients set a rigid fixed budget for the project, though they accepted that the flexibility they required would mean a higher cost relative to enclosed space than a more conventional building. For instance, the 6-metre span rooflights provided natural daylight over the entire factory floor but were also designed to collapse in the event of a fire and thereby become a smoke vent. These were a comparatively expensive item, made from GRP using techniques acquired from yacht manufacturing and not used in building construction before. The inclusion of these elements meant that the building control authorities allowed the factory floor to be used as a single space – compartmentation would have fundamentally compromised flexibility in use with the inconvenient and time-consuming necessity to erect and dismantle partition walls during any change in operations.

Though there were many new factors at work, initial detailed design utilised principles developed for the Herman Miller building. The engineers, Whitby and Bird, were only brought in after the concept stage and it was the architects who created

Fig. 8.4 Exploded axonometric of the construction. Cladding panels are located with satin-silver anodised aluminium clamps fixed to mullions made from standard shelving uprights stiffened with flat steel plates.

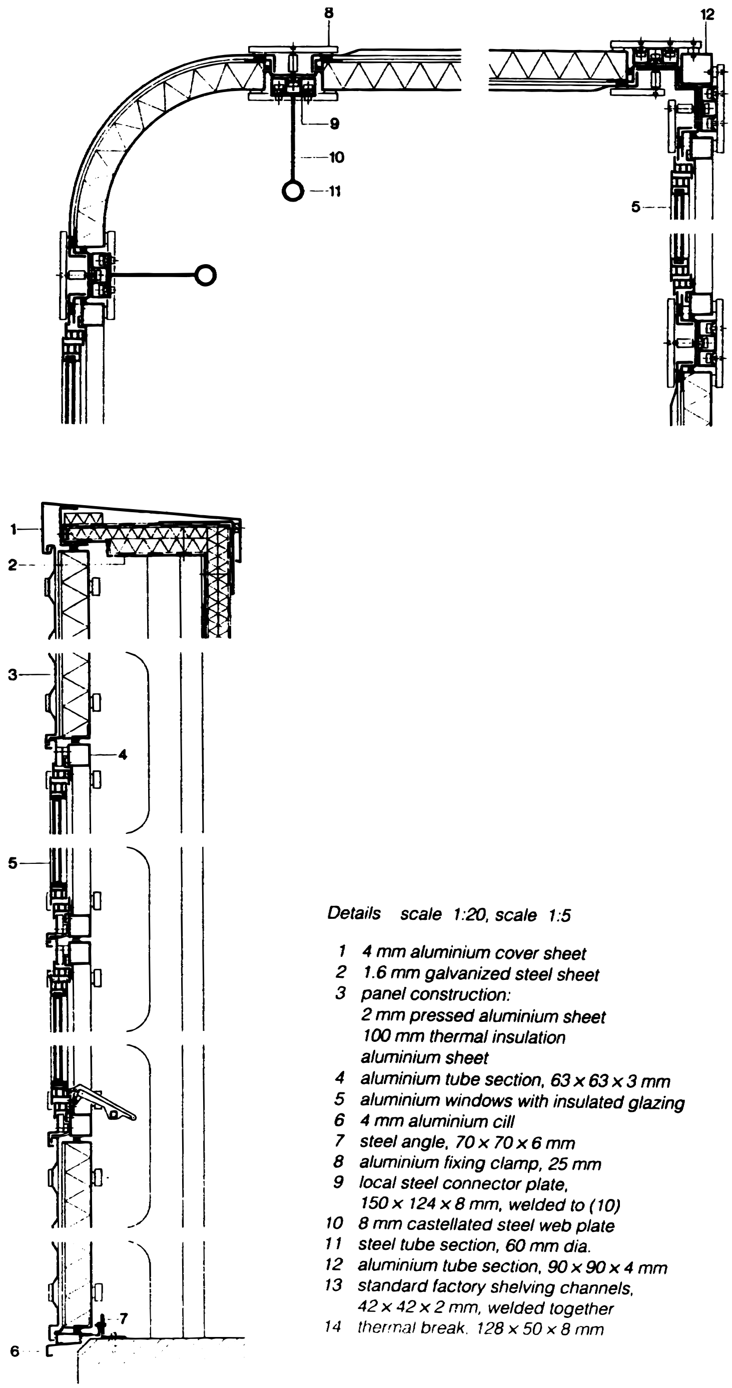


Fig. 8.5 Cladding details, top: horizontal section, bottom: vertical section.

the main structural form and controlled detailing. The image of the building as a high-quality work of engineering was strongly influenced by the nature of the client's activities and the processes that were to be carried out within the building. The demountability and movability of components was seen as an integral part of their design and it was decided that they should therefore convey this factor in their visual appearance (Figs 8.3–8.4).

The largest single movable elements are the office and administration pods which have no fixed position and have been designed to visually convey their portability. Their construction consists of a space enclosure system embraced by a bright yellow painted steel framework, which has legs terminated with flat disc-like foot pads. The factory floor is designed to support the pods at any location and all services including pumped waste water are routed at ceiling level through a comprehensive matrix of servicing points. The pods are moved very easily by lifting the legs onto air-supported lifting devices originally designed for moving stage scenery. One of the factory's fork lift trucks then tows the pod to its new location. A second fork lift truck is required to tether the pod in the rear, as once these large modules are moving their inertia means they need to be effectively slowed down when they reach their new location (Figs 8.6–8.7). Eight additional pods are to be constructed for use in the Phase 1 part of the building.

The subcontractors were required to submit a mock-up of the demountable cladding system with their tender. Harty Holdings were the only company to do this and it is significant that they won the order. The cladding system was based on the Herman Miller pattern but improved so that the panels could be removed by simply loosening and swivelling an aluminium clamp (see Fig. 8.5). The system incorporates a wide variety of panel types including aluminium face, louvred, windows, plus escape, personnel and loading bay doors. The system was tested by the manufacturers in prototype form for wind and rain penetration. Standard Unistrut shelving system uprights, reinforced for their new role, were used for the cladding panel substructure.

Because of the unusual techniques used in the building's construction, specialist subcontractors were carefully selected in advance of the main contract being let and their inclusion made a condition of the tender for the main contractor. The first phases of the project were more difficult contractually due to the inclusion of specialists unfamiliar with building industry methods. For example, the

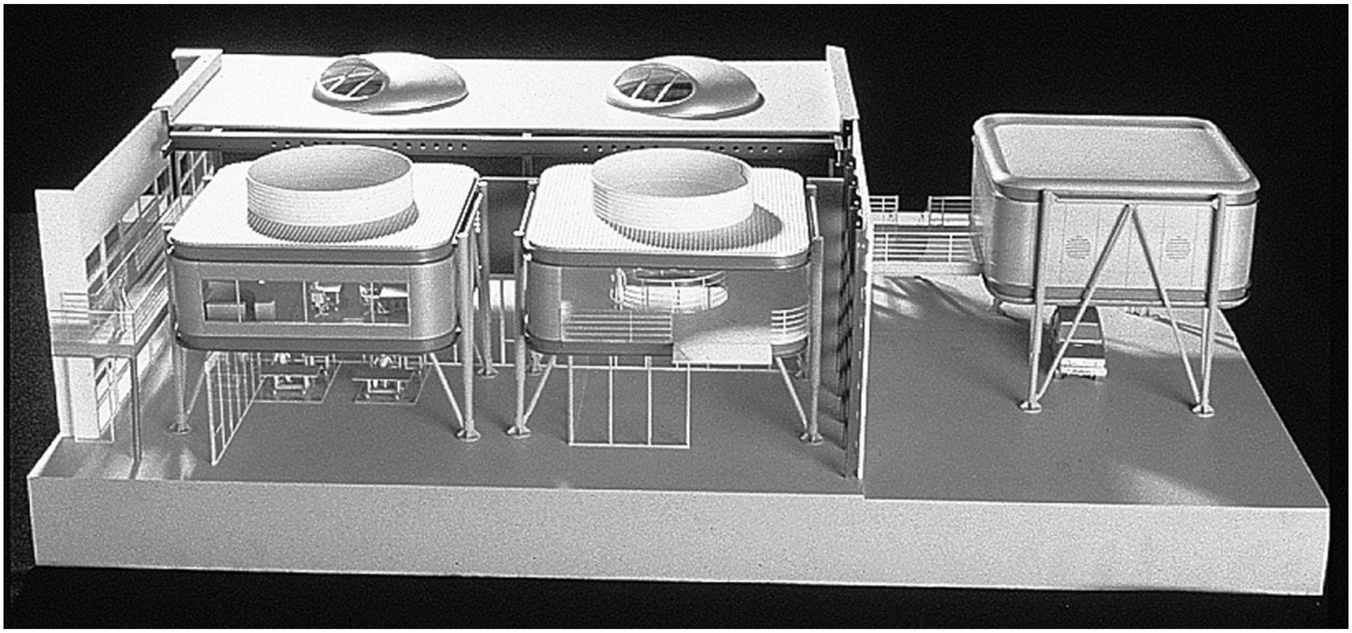


Fig. 8.6 IGUS factory. Model showing internal and external pods.

main contractor, Trafalgar House Construction Management, working in partnership with German company Walter Bau-Ag, was wary of accepting the GRP rooflight manufacturer who was unused to building industry procedures. This was solved by Fischer Glass, the glazing system subcontractor, adopting Fibreglass Construction, the GRP manufacturer, as a specialist subcontractor to their work. In subsequent phases, as the contractors became used to working with each other and confidence in each other's abilities was established, such issues became less problematic.

Nicholas Grimshaw and Partners' standard procedure is to spend more time in detail design than might be the case with many other architects. This feature of their design process is significant with regards to their involvement in the development of innovative constructional systems. Because of this, the lengthy detailed design process that the IGUS project involved was seen as fairly normal, despite the fact that it constitutes the most flexible static building ever built. However, the IGUS project did involve the architects working more closely with the contractors on site than ever

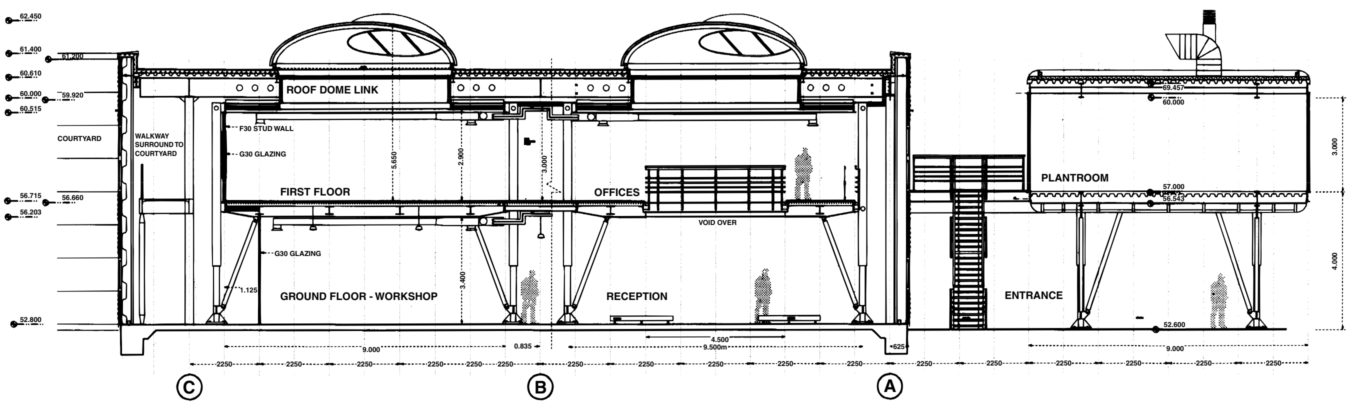


Fig. 8.7 Section through the IGUS factory showing internal pods, in this case used as offices, and an external pod used as a plantroom.

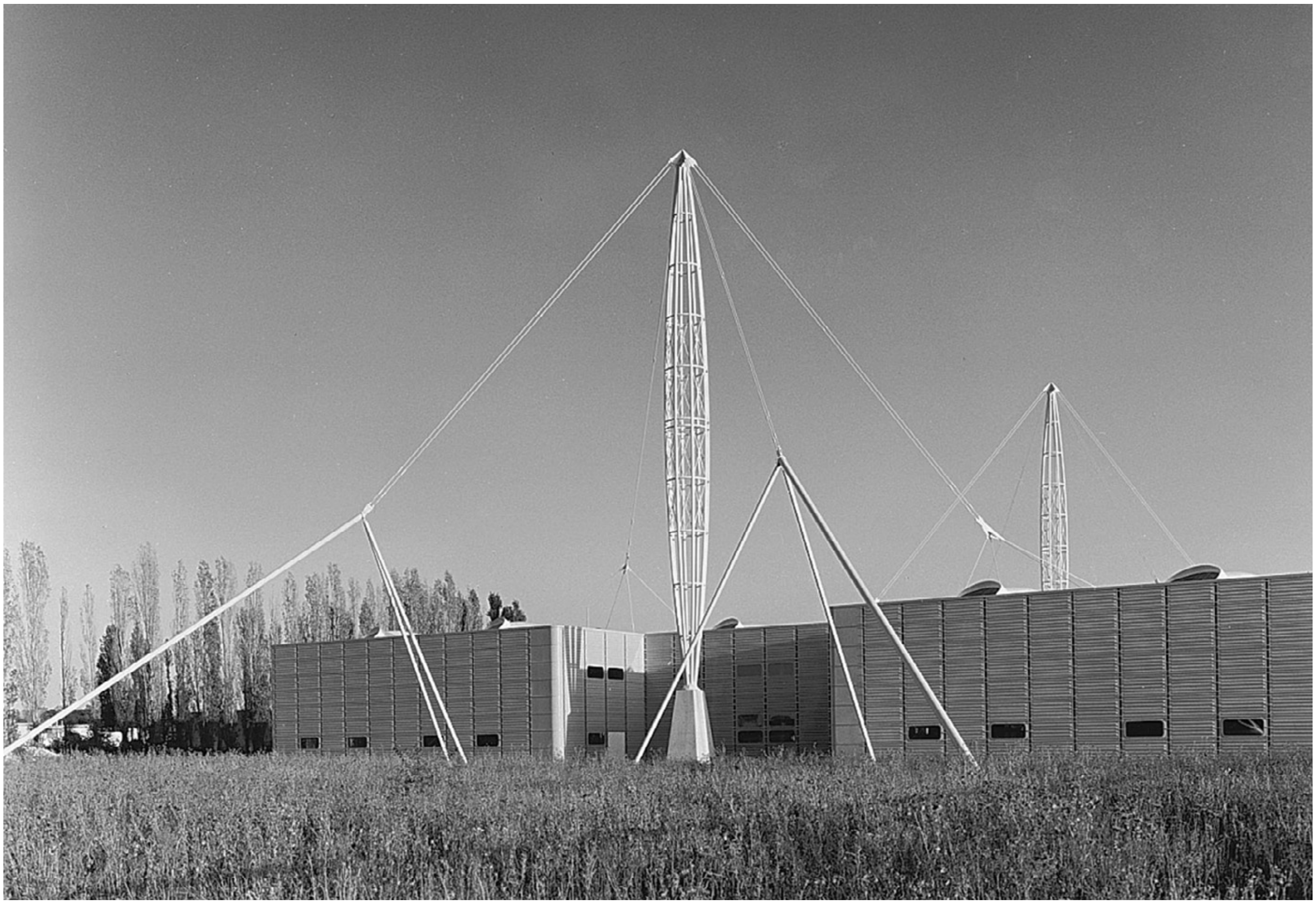


Fig. 8.8 The first phase of the building was built with two masts and one and a half courtyards complete.

before, partly because they were British architects working with mainly British contractors in a foreign country, but also because part of the architect's role was to act as the client's representative, almost to the point of becoming part of the client's organisation during the construction period. Bryden had his own office in the IGUS factory for the duration of the contract. A German consultant site representative (Buro Weiss), called a *bauleiter*, was used to smooth the differences between architects' responsibilities in Germany and the UK and a German Verdingungsordnung für Bauleistungen (VOB) building contract was used.

The unprecedented flexibility required for the design added greater complexity to the construction process. Though this was a central part of the architects' concept, its employment in every detail of the design was enthusiastically supported and even driven further by the client, who constantly sought the most flexible solution to detail design issues. The designer was constantly asked to reject 'special' situations which could not be met within the modular system. For example, a loading bay door with its particular problems of dock levellers and different opening sizes was originally to be solved with non-replaceable components, however, the client insisted that it be redesigned so that it could be relocated anywhere into the standard cladding module. A removable secondary structure was therefore designed to fit into the standard system to provide the extra strength and fixings for a movable door surround.

Though design procedures were more complex, actual assembly systems became simpler. As the design was refined to allow for easy movability, careful attention to detail meant that the hybrid building procedures that utilised standard products in conjunction with specialised components caused no special problems. All phases of the building have so far been completed on time and on budget.

Fig. 8.9 Internal view. The factory floor is completely clear of services which are distributed at roof level.

The erection of the building required no special operatives. A project manager from the manufacturer was involved in the erection of the prototype and communicated his experience initially to the designers, and subsequently to the commercial team of cladding fixers on site. Factory workers were instructed in disassembly and assembly procedures for future changes. These have already taken place in the existing operational phases without significant problems. Despite the client's enlight-

Fig. 8.10 An internal pod with movable access stair to upper level.

ened approach, project architect Mark Bryden believes that Blase was not aware of just how flexible their factory building could become. The rapid redeployment of machinery and operatives within the building form has led to even more radical methods of working. IGUS no longer feel they occupy a passive building but one that responds to their needs. Its flexibility encourages alternative operation methods not envisaged before occupation. The client has also realised that such flexibility means that the entire function of the building can change if required, for example to a research and development facility for their own use, or even commercially viable alternatives such as an office building or supermarket.

Instead of a facilitator the building fabric has become an interactive factor in the production process which can lead to new methods of working. A 'solar system' map with magnetic counters representing each of the production team members is displayed at the entrance to the factory showing where everyone is working (Fig. 8.11). Communication has become an essential part of innovative manufacturing practice and special creative weekends have been established to foster the creation and development of new ideas. A clear awareness of the special flexible qualities of the building in which they work is an integral part of this process and all the factory team are knowledgeable about this.

Fig. 8.11 The main entrance area. The 'solar system' magnetic sign board is seen to the left. Entry is below an external pod which is used as a canopy and between two internal pods which contain office space

Because of the care taken in the building's design, very little has been built that the architect feels is unsatisfactory. Significantly, reservations are generally related to immovable objects such as services connections and meter positions. None is of a conceptual nature. The sort of work that an architectural practice is asked to do is very much related to its track record. Technologically based work such as the Herman Miller warehouse led to Günter Blase's interest in Nicholas Grimshaw and Partners and the practice places particular emphasis on the qualities it feels are important in its marketing. New clients have approached the practice on the basis of the IGUS factory, however, this has largely been in relation to its image and appearance rather than the less easily appreciated flexible basis for its operations. This aspect of its design has been inspired and driven forward by the particular requirements of the client and his special appreciation of the way a building can prove a positive force in the operation of the manufacturing process it contains. It is of great significance that the client appreciated and understood this factor before selecting his architect, however, the designer has acted as a pro-active force in bringing these ideas to fruition and has even exceeded the clients' expectations in this area.

Of what value is the example of the IGUS factory in the understanding of portable architecture? Though it is a static building, two of the main factors that influenced its creation are also found in the design of movable buildings – its use of demountable construction and the advantage it takes of technology transfer. Demountable modular elements are used in the IGUS factory to allow for dramatic changes in the way production lines operate, changes which can be made in a matter of hours or days. The consistent developmental process utilised in the building's design has led to new systems being refined in detail to the stage where they enable these changes to be made with the minimum of difficulty, using non-specialist operatives. The quality of the product design (for in some ways this is what it has become) means that components can be moved repeatedly without damage or deterioration in their operation. This aspect of detailed design is an integral requirement for demountable portable architecture and proof of the similarity of design issues between the two superficially different types of building project.

The incorporation of materials and techniques found in other applications has not been implemented in the search for a new image, but as a tuned solution to particular practical problems brought about by the building's function. The IGUS brief required that the building do more for its user than could be achieved with conventional building methods. This demand has affected not only the way the building has been designed but the way it has been procured, manufactured, and constructed. Good portable architecture also consists of examples of buildings that have broken the boundaries of conventional practice and, by necessity, many use technology as a vital component in their design.

The IGUS factory therefore stands as an example of the way in which building design and manufacture can benefit from the application of alternative operational philosophies and materials and construction technology. In this particular project the innovation has resulted from the specific requirements of a particular client and the operational system he has developed, however, its principles and details are equally applicable to many other manufacturing processes and the buildings that contain them. There are many similarities between the portable building and the flexible building but perhaps the most important may be that principles originally identified by enlightened clients and their architects can be recognised by others, and ultimately be of value to all.

Further reading

Bryden, Mark; Whitby, Mark; Blase, Frank and Greenberg, Stephen. 'Factory with Flexibility Built In' *Architects' Journal*. 24 March 1993, pp. 33–44.

Powell, Rowan (ed.). *Structure, Space and Skin: The Work of Nicholas Grimshaw and Partners*. London: Phaidon. 1993.

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Antarctic Expedition Tent

Date: **1985–1986**
Client: **Roger Mear**
Engineer: **Buro Happold:** Ian Liddell
Cost: **£1200**

MEC Arena, UK

Date: **1990**
Client: **Mobile Exhibition Centres Ltd**
Engineer: **Buro Happold:** Ian Liddell, Angus Palmer, Mike Cook
Contractor: **Tubeworkers;** Audio Visuals: **Light and Sound Design;** Roof: **Landrell Fabric Engineering, Chepstow, UK**
Cost: **£700,000**

Radha Soamy Satsang Beas (RSSB) Shelter, Haynes Park, UK

Date: **1993–1994**
Client: **RSSB Foundation**
Engineer: **Buro Happold:** Paul Westbury, Colin Gill, Ian Liddell
Contractor: **Landrell Fabric Engineering, Chepstow, UK**
Cost: **£660,000**

Consulting Engineers Buro Happold were established in 1976 as a multi-disciplinary practice that could provide within one organisation all the different aspects of engineering skill necessary for work in the building industry. The practice now includes teams that deal with civil and structural engineering, mechanical and electrical engineering, building services and environmental engineering and infrastructure and traffic engineering. The practice's principal partner and founder was Sir Ted Happold who was also Professor of Building Engineering in the Department of Architecture and Building Engineering at the University of Bath. His involvement was a significant factor in the development of the practice's innovative yet pragmatic approach to developing building engineering techniques.

It is particularly in the field of lightweight structures that Buro Happold's experience is valued at an international level. Although such projects form a relatively small part of their total workload, the dynamic and exciting appearance of the flexible skin and air-supported structures with which the practice has been involved, has led to a higher profile for this sort of work. The work of the special structures unit is founded on their knowledge of the new materials and technology that are now available to the designer, and the extended possibilities they provide. The design process of this unit is also at the forefront of technological development. Buro Happold use computing to support all aspects of their design and testing work, including finite element and dynamic relaxation structural analysis, thermal analysis, lighting analysis, ground and highway modelling and fabric and cable-net patterning and dimensioning. Much of this work is done on in-house generated software programmes based on a Hewlett Packard UNIX system and a Silicon Graphics network. Some of these design programmes are now being prepared for limited commercial use with personal computers.

The work on lightweight structures has resulted in a long series of projects that vary dramatically in scale and function. Most have been for permanent buildings where the lightweight solution has meant efficient utilisation of materials and construction techniques, and have been adopted for the resultant reductions in building cost and site erection times. The designers have also recognised that lightweight structures have particular value in the design of portable buildings, the main advantages being that membranes have the potential to be folded for transport and the compressive structural members can be few in number, demountable and lightweight. The range of portable buildings that the practice has designed, if fewer in number than the permanent ones, are no less varied in strategy and form. The three examples here have been selected because they exhibit the wide range of functional problems that have had to be solved, and also they are examples of a strategic approach that explores applied design routes in a developmental way with the aim of discovering appropriate solutions to new problems with relatively little risk.

Antarctic Expedition Tent

It would be unrealistic to describe structures such as a one-man tent as portable architecture as their function relates to simple immediate shelter rather than the complex activities associated with a permanent (if movable) dwelling. However, the technology which is applied in this project for a severe environment shelter is nevertheless of interest. It is also significant that despite the scale of the project, Buro Happold engineer and founding partner Ian Liddell used a range of skills that may also be applied to much larger problems.

The brief was to create a demountable shelter for Roger Mear for his 'In the Footsteps of Scott' journey to the South Pole in 1985–86. Mear and his two companions planned to walk across Antarctica for seventy days, each pulling a sledge which would carry all their supplies, communications equipment and shelter. The extreme conditions tent then used by the British Antarctic Survey was a pyramidical structure that used wooden poles and weighed 28 kilograms. The alternative lightweight mountain tents were simply not strong enough for the extreme weather conditions at the South Pole. The designers were aware that though they must create a lightweight solution, easy to erect even in extreme winds, it must also be completely reliable – if the shelter failed this would almost certainly lead to the death of the occupants.

Liddell's solution was not to change the form of the tent dramatically (as a regular dome shape contained space efficiently and could accommodate shifting winds) but to employ erection and transportation methods tuned to the conditions of use and utilise modern materials to provide low weight combined with high strength. As the tent was to be carried on a 2.4-metre long sledge, it could be transported partly assembled rather than in completely demounted form. The structure of the tent was therefore designed as an umbrella-type structure that would be transported as a long bundle with six glass-fibre poles contained within a tent membrane. The poles were fixed with a removable pin (allowing replacement in the event of failure) to a machined aluminium radial element at the top of the tent. To erect the structure the tent fabric was pulled down to the end of the poles which were then sprung under compression into a curved shape in the fabric. The bottom of the poles

Fig. 9.1 Antarctic Expedition Tent, Buro Happold, 1985.

were then pulled out with the continuously attached ground sheet into the 2.5 metre diameter floor plan and tied down with snow anchors and, for additional stability, to sleds and skis stuck in the snow.

The tent skin was made from Goretex fabric which allows moisture from inside the tent to pass through, combined with a nylon outer layer and a PTFE skin bonded to the underside. A lightweight inner membrane was also used to provide an air buffer zone which helped to raise the internal temperature. Kevlar tapes were bonded into the fabric to provide additional strength. A prototype was tested in the 9.2 metre wide wind tunnel at Farnborough Research Station.

The tent was used successfully during the expedition, providing shelter for Mear and his two companions; however, disaster still affected their mission as their support ship was crushed in the pack ice and sank leaving the explorers stranded at the South Pole. Fortunately they were able to take shelter at the American Antarctic research station.

Mobile Entertainments Centre (MEC)

This project was built in 1990 as a speculative venture for a new company, Mobile Entertainments Centre Ltd, a subsidiary of the Christian Salveson transport group. Originally conceived as a column-free mobile arena suitable for rock concerts, the brief was altered to encourage greater flexibility as it became clear that such a building could have many other uses. The key features of the building were that it was to be capable of moving from place to place, would have a completely column-free span, and that its interior would be a black-out space that would allow comprehensive control of the interior visual environment, day or night. As well as carrying the roof, the structure had to be capable of supporting complex sound, lighting and other show equipment. It was also desirable that the building have a unique image and, if desired, be capable of extension into a larger form at a later date. The result was a venue which can be erected and dismantled in three to five days depending on conditions and provides controlled environmental conditions for an audience of up to 6000 people.

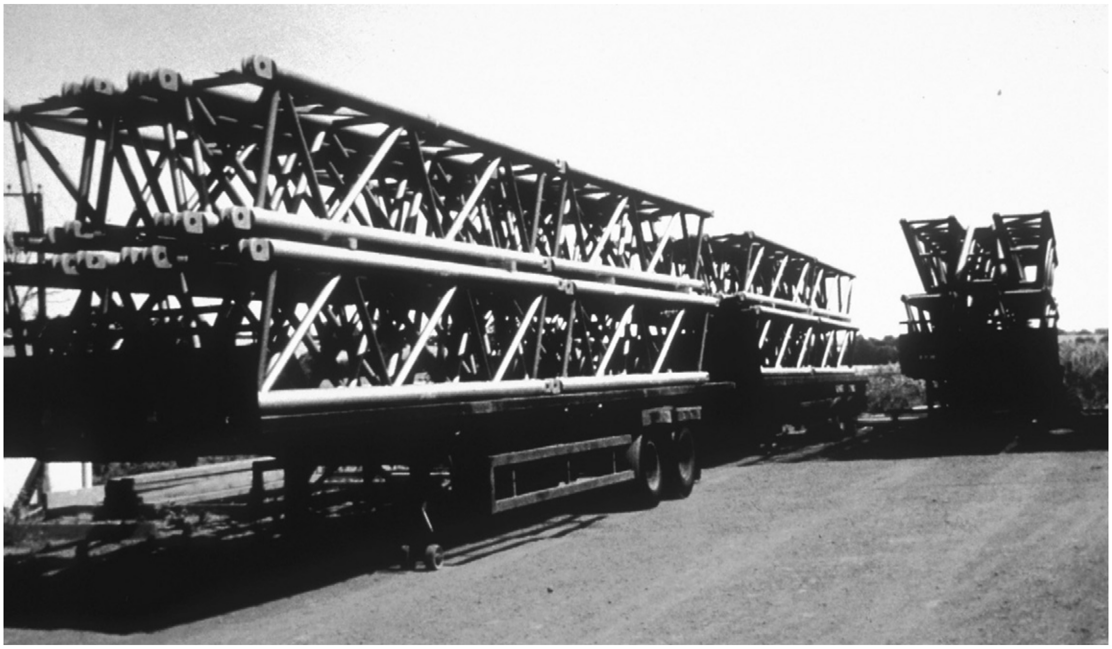


Fig. 9.2
MEC Arena, Buro Happold, 1990. The structure is transported on articulated lorry trailers.

The main structure of the MEC is a 1.4 metre deep steel lattice portal frame repeated at 12.5 metre centres. These main elements are braced longitudinally by trusses that span between them at right angles. The clear span of the structure is 63 metres and the clear height is 19 metres. Panels of PVC-coated polyester membrane, measuring 23 by 12 metres are fixed to the frames and stressed on site to reduce deflections. The top part of the building consists of two cone-like membrane structures suspended from a pyramid of four aluminium trusses, each 50 metres in length (Fig. 9.3). The bottom edges of the pyramid are fixed to the top edge of the portal frame horizontal bracing members. The pyramid material is also PVC-coated polyester and all the membranes are coated internally with a carbon black inner layer to exclude light (Figs 9.4–9.5). The length of the building is 88

Fig. 9.3
The tripod structure that supports the apex tension membrane is erected separately from the main, heavier structure which supports the side membrane panels and the internal performance equipment.

Fig. 9.4 Deployment of the apex membrane.

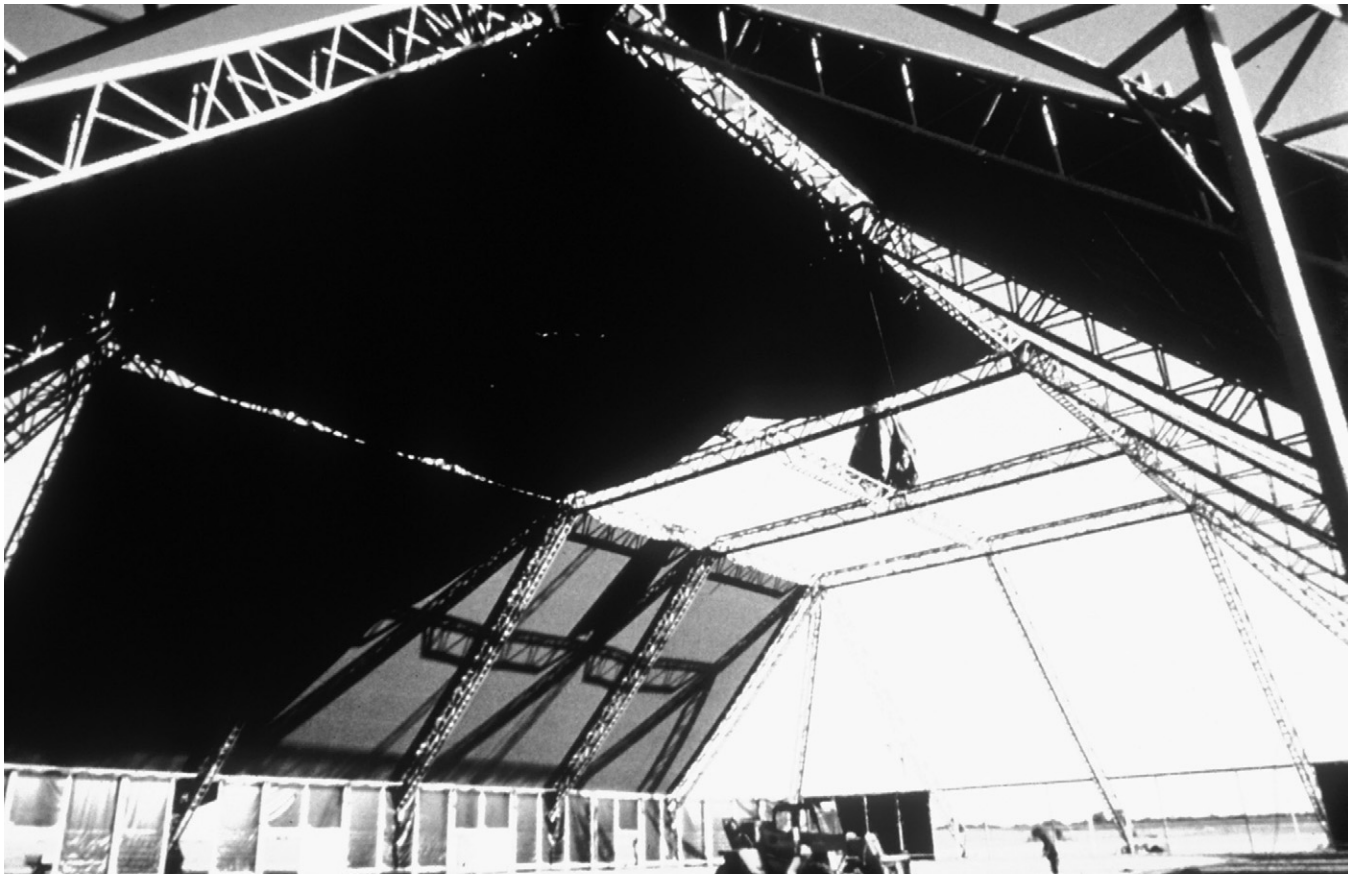


Fig. 9.5 A modular partition system is used for the ground level perimeter cladding.

Fig. 9.6 The completed building.

Fig. 9.7 Interior. Note the articulated lorry hanging from the structure.

metres though this is infinitely extendible by the addition of extra portal frame bays and pyramid structures.

Depending on the amount of servicing, lighting and sound equipment carried, the entire arena can be transported on between twelve and fifteen articulated trailers (Fig. 9.2). The foundations are 1.4 metre square steel grids that are fixed into the ground with proprietary helical anchors. The portal frames are erected using a lorry-mounted crane. Riggers can then move through the catwalks within the frames to erect the skin of the building and all its services. The frames are made to withstand a substantial load of up to 30 tons, a capability which was dramatically displayed at the building's opening when an articulated lorry was suspended internally from the roof. A vertical wall of aluminium frames and fabric panels that connect to the flat profile of the roof panels is erected around the perimeter.

This building follows in the tradition of the circus tent, a familiar mobile entertainment venue. However, where it differs is in the significant advantages it offers for contemporary entertainments which require much more sophisticated levels of presentation to meet public expectations. It is a much larger portable arena than normal with a total contained area of 5544 square metres which can operate in black-out at any time of day or night. The amount of equipment which can be suspended above any part of the arena is adequate for the most sophisticated shows and this can be accessed at any time during the preparation stage or during the performance. Perhaps its most significant advantage is that it is a completely column-free space which provides unlimited flexibility in layout and use.

Radha Soamy Satsang Beas (RSSB) shelter

CASE STUDY 09

The Radha Soamy Satsang Beas (RSSB) is a religious organisation that has its English base at the rural Haynes Park estate in Bedfordshire. Each summer the group has a major religious meeting when up to 25,000 people gather together. Previously the group had rented a hall at the National Exhibition Centre in Birmingham; however, the use of this venue created a number of problems. Besides the considerable expense of renting such a high-profile facility, there was also the problem of how the people who took part could be accommodated. In addition, whilst it allowed everyone to gather together in one space, the NEC is a venue more conducive to commercial events such as trade shows and pop concerts rather than religious meetings.

In 1993 the group decided to investigate the possibility of holding the event at their own headquarters. There was plenty of open space for the erection of a meeting hall, though a permanent structure would not receive planning permission on such a sensitive rural site, and in any case it would stand empty for all but two weeks of every year. The group made contact with commercial marquee hire firms who were able to provide a covered space of the size required, however, this solution would have the major problem of being made up of a large number of small units, each of which would have many vertical poles and associated tie down ropes. In addition, when it rained, all the water would run off from these separate units into the covered space below creating a noisy, wet and uncomfortable environment. It was clear that using commercial marquees would provide only a crude solution.

Buro Happold are regularly involved with the manufacture of commercial marquees, establishing the certification process for the rental tent and

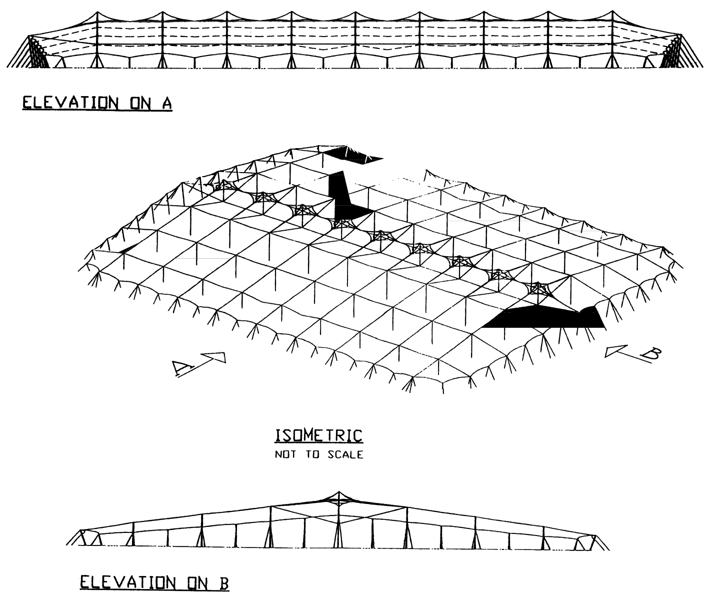


Fig. 9.8 Radha Soamy Satsang Beas shelter, Buro Happold, 1993. Isometric and elevations.

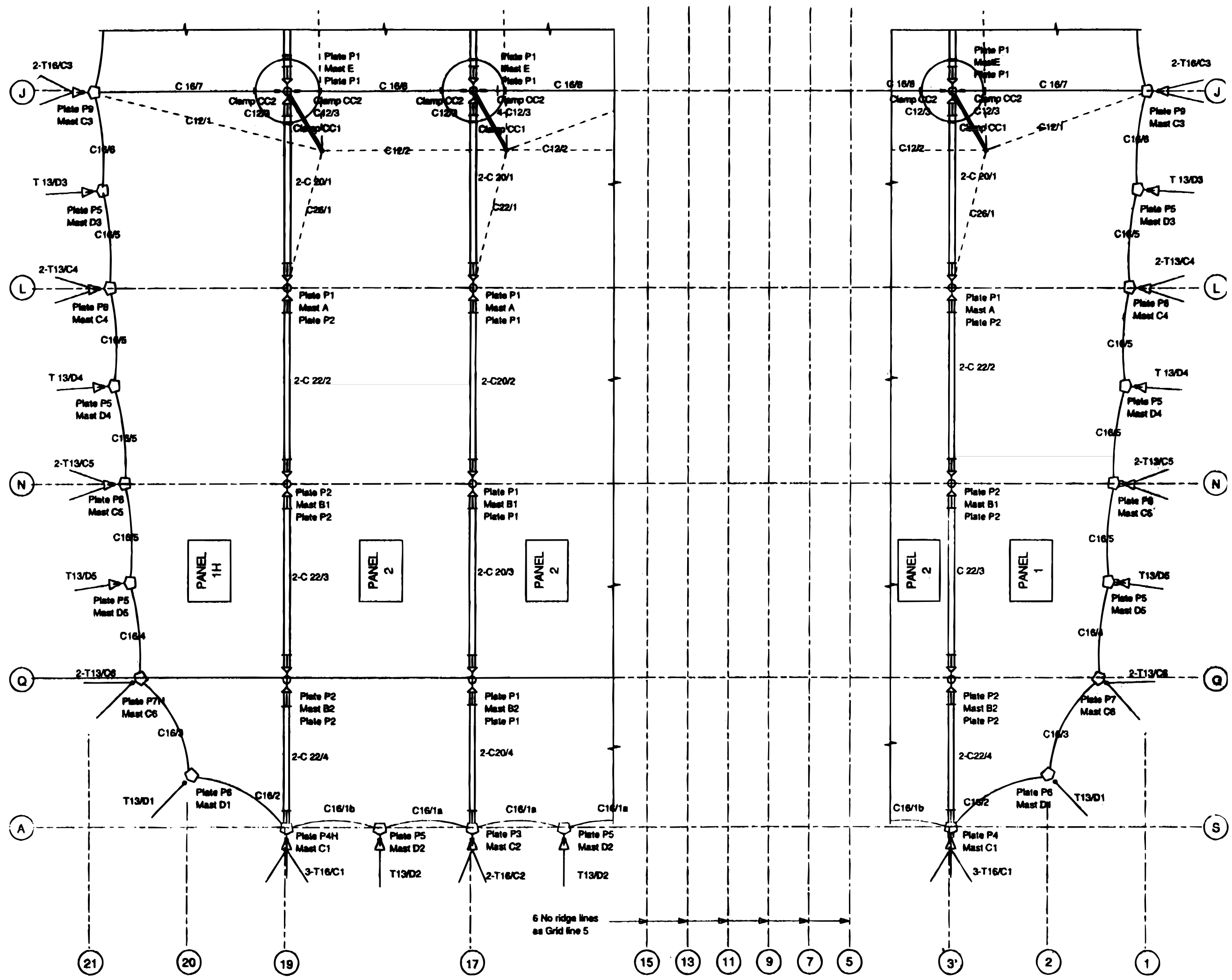


Fig. 9.9 RSSB shelter, mast and membrane layout plan. Each foundation plate, mast and membrane panel is coded to facilitate component recognition during erection.

marquee industry which is regulated by the Made-Up Textiles Association (MUTA). They have also designed rental tent systems and have worked on every aspect of their design and construction. Their contact for this commission came through a contractor directly involved in this industry – Lance Rowell of Landrell Fabric Engineering. It became clear that the clients required an awful lot of building for very little money, approximately 20,000 square metres of covered area for a total budget of only £33.00 per square metre. In addition, the sensitive site meant that the building would have to be erected only for a limited time, leaving no visible signs of its presence above ground for the remainder of the year. Planning control restricted the building to eight metres in height, creating further problems for a large span structure. The brief required that the building consist of a single space with as few intermediate supports as possible and that all rainwater should be routed to the perimeter.

The solution was to create a single lightweight tension membrane structure that would cover the entire area, though in order to aid manufacture, transportation (from factory to location and then site to storage building each year) and erection, it would be made up in panels 60 metres long by 15 metres wide (Figs 9.8–9.9). This membrane accounted for 94% of the total budget. The membrane would be elevated from the ground by a series of minimal compression members with a Tensegrity structure in the central section to provide a greater clear span.

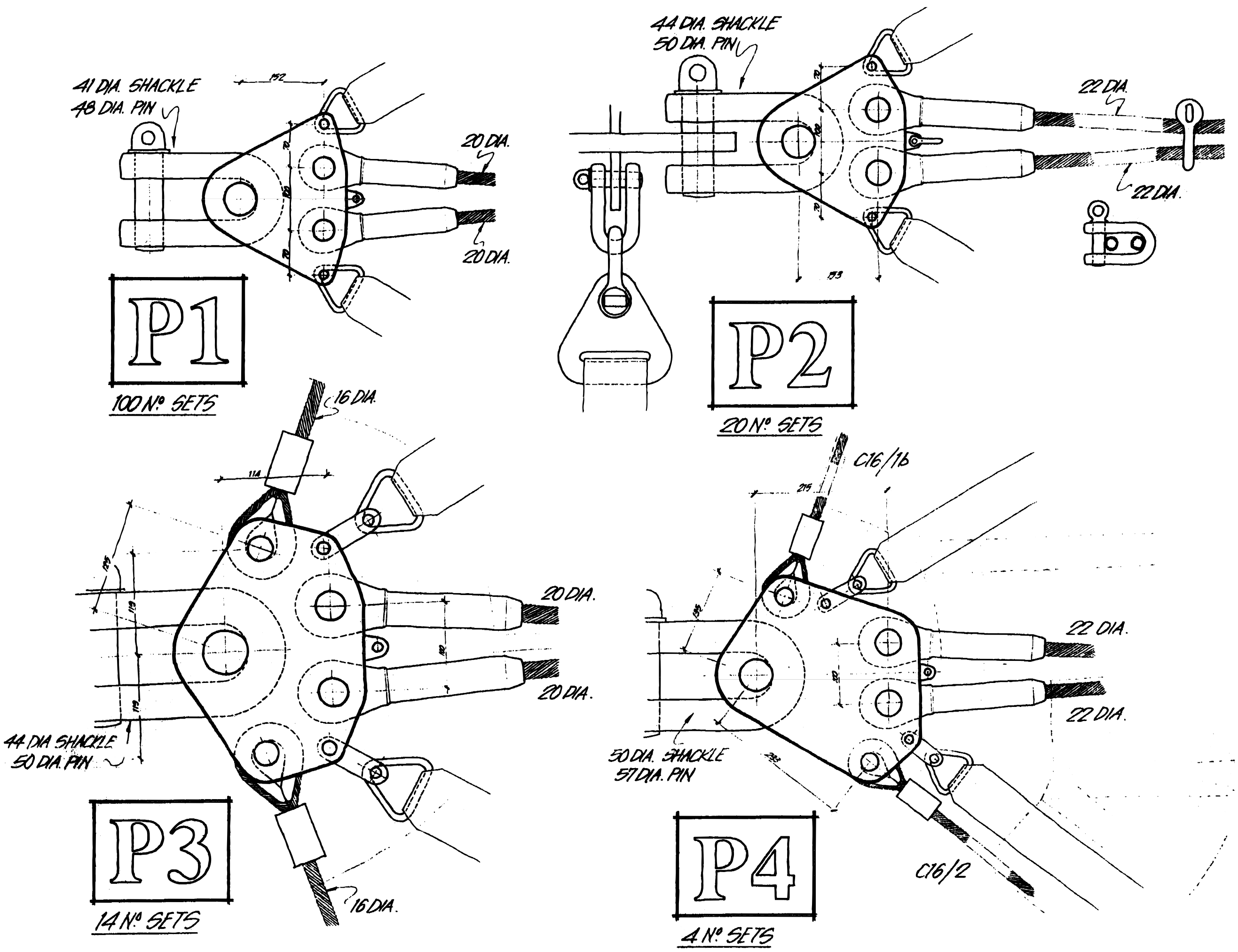


Fig. 9.10 Steel plate details showing cable and webbing connections.

Fig. 9.11 RSSB shelter, assembly of membrane at ground level. To the left is a line of masts in position ready for erection.

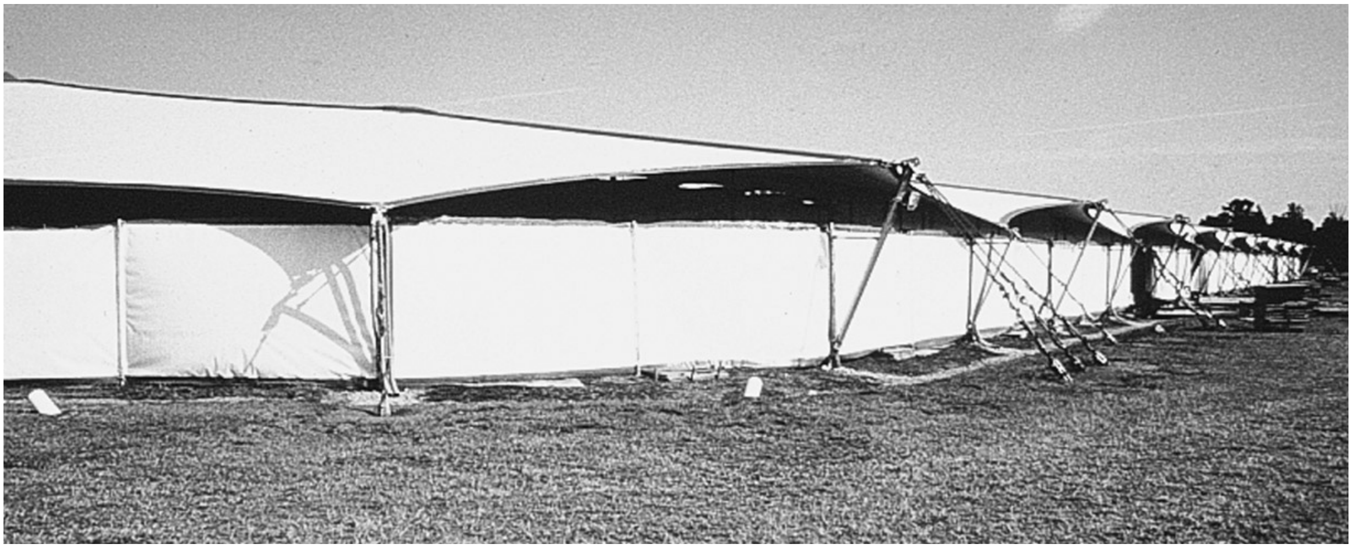


Fig. 9.12 The masts closest to the edge of the building are splayed outwards though the perimeter membrane is vertical.

No special equipment is required for the erection procedure which is undertaken by RSSB group members themselves (Fig. 9.11). First the panels are laid on the ground with the intermediate columns laid flat below them in the required positions for erection. The panels are joined together on the ground using a clamped double joint with a rain flap that folds over the top of the connection like a flashing. A continuous steel cable runs from one side of the building to the other to accommodate the main tension forces once the membrane is lifted into position. This is necessary because of the restriction in height that prevented the use of iconoclastic curves which are normally used to give rigidity to membrane structures. The use of the cable allows the curve to be much shallower and still maintain rigidity.

After the membrane is assembled, one edge is lifted by operatives and a small powered trench digging machine enters beneath the skin. The bottom of the first compression pole is placed in a capture tool in the bucket of the vehicle which pushes the pole into position, simultaneously raising the membrane. A helper places a pin in the pole base when it is in its mounting plate. The process is then repeated until all the poles are erected. As this building is to be installed in the same place each year, the ground level mounting plate is set into a small concrete pad just below ground level, however, if required it could also have been placed on a removable spreader pad secured by ground anchors. This would make the building fully transportable to any venue. There are three sorts of columns: a small tubular edge column which is inclined against the edge load, an internal vertical tubular column which is placed in intermediate positions, and a triangulated vertical column which is used on either side of the central column-free space. The central ridge is supported by a Tensegrity system which incorporates a small elevated compression membrane between top and bottom tension cables. In the centre of this space there is a circular hole in the fabric to provide light and ventilation with an elevated cap that prevents rain from entering. When the entire shelter is erected the whole structure is tensioned and stiffened by stretching the cables across its width and a continuous cable that skirts the perimeter of the membrane. Wind forces are important in a structure of this type and the details have been designed to counteract upward lift as well as downward. In some circumstances the entire structure will lift from the ground, restrained only by pins in the column bases.

The RSSB organisation members undertake the entire erection of the tent themselves, in fact during manufacture they were called to Landrell to manhandle the large sheets of fabric around the machines that were used to make the joints. Buro Happold trained the erection team themselves and have consciously designed all the joints and connections to be very simple, requiring no special

Fig. 9.13 The internal space. A Tensegrity system supports the central bay with openings for ventilation and light protected by separate conical membranes. The columns on either side are triangulated members, the rest are tubes.

tools or skills in their operation. Despite the simplicity of these joints, great care was taken in their design and each junction was drawn at full scale before manufacture (Fig. 9.10). The first time the building was erected it took a week, the second time only three days. The project was run as a design build package, and from commissioning to the first erection on site was ten months. The galvanised steel supports have a minimum design life of fifteen years and the fabric, because it is to be demounted and folded away on a yearly basis, a life of about ten years – a permanently erected fabric structure would last longer.

This structure not only provides a remarkably efficient coverage of space for a very low price, it also enables a building to be erected where no building would normally be allowed. For the rest of the year it leaves minimal impact on the site. Erecting such a temporary building has added to the sense of occasion at the annual meeting of the group in that they now gather early in order to put together their own dedicated shelter, rather than simply occupying an anonymous commercial shed. The quality of the space is also remarkable, a giant translucent pavilion in the landscape, linked in character and imagery to traditional tent-like

Fig. 9.14 External view. The building has a very low profile despite the larger spans involved.

shelters but clearly a modern phenomenon that utilises contemporary materials and structural techniques.

These three structures are remarkably different in scale and purpose yet there are several significant similarities between them that not only indicate the skills of the design team that has responded to the specific problems that each provided, but also informs the general nature of portable building design and construction.

Each project utilises the concept of lightweight structures as a major part in the design philosophy. All use membranes of one sort or another in their construction. In each case it is the main barrier that protects the inhabitant from outside environmental conditions. Surprisingly it is the Antarctic shelter which is most sophisticated in this case, utilising new technology materials to provide not only a strong lightweight solution for the harshest conditions to be found on the Earth's surface but also utilising twin skin construction and breathable fabrics to maintain an operational internal environment.

Perhaps the most significant common factor between these three projects is that they are not based on some dramatic revolutionary concept which is specifically related to portable building construction but are developments and improvements on patterns of construction that have gone before. The Antarctic tent uses the same form as military campaign tents that have been in use for hundreds of years, yet also utilises relatively new compressive materials to improve the form (glass-fibre poles that bend to rigidise the skin) and new membrane materials to improve performance (Goretex breathable fabrics and very strong Kevlar tape). The MEC utilises a portal frame system that is a familiar structural pattern, however, its new connections, foundation details, and lightweight construction are adapted to enable portability. The RSSB evokes a traditional tent form, greatly enlarged to dramatic scale but basically the same in principle as thousand-year-old patterns. The genius of this design is the careful, simple detailing that allows a large building to be erected without the use of complex heavy machinery. The materials and principles used in the MEC Arena and the RSSB shelter are also those used in conventional permanent building construction, though it is quite clear that when used in portable building situations, attention to logistical and constructional detail becomes more crucial. The principal difference is that portable building construction requires more efficient and innovative procedures to provide practical solutions for complex demanding problems. The impossibility of using a standard solution has been the starting point for each of these designs and this has not only led to more appropriate problem solving for each specific project, but also to the creation of new approaches that may be of use in related areas of building design.

Further reading

Happold, Ted. 'Chariots of Fire' *Patterns 5*. May 1989, Bath: Buro Happold.

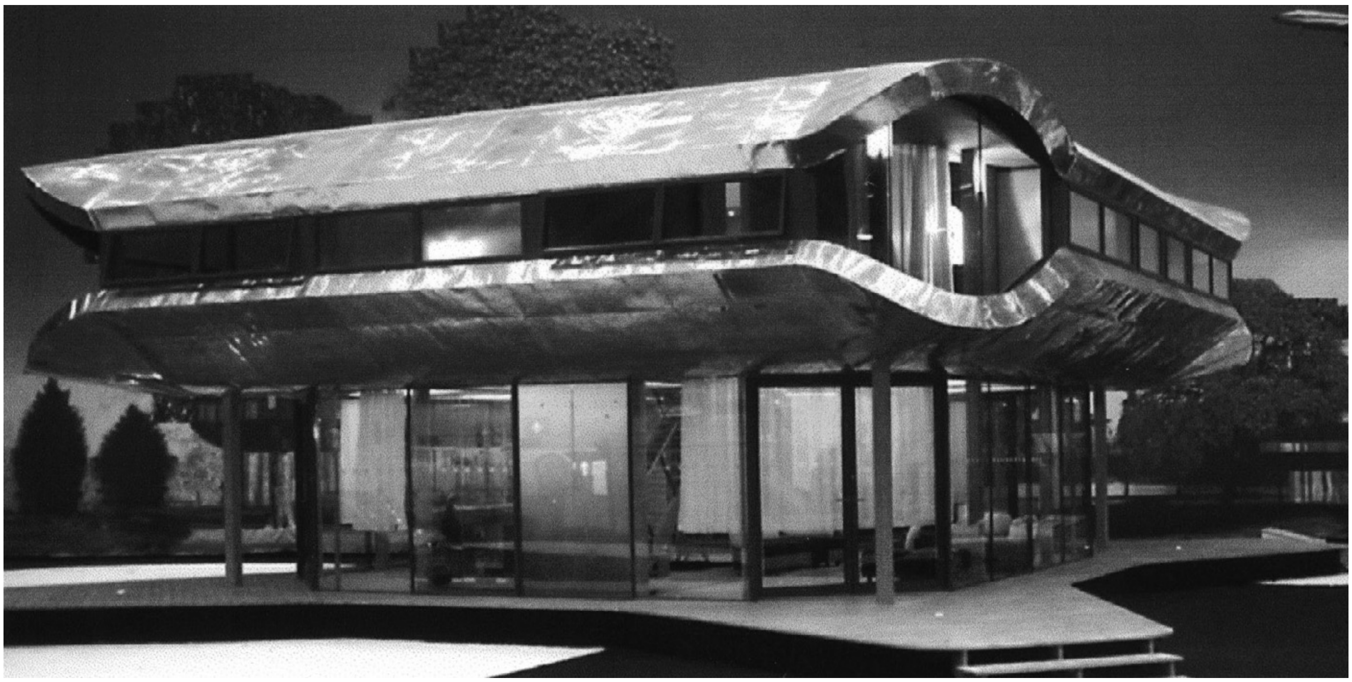
Liddell, Ian. 'Journey to the South Pole' *Patterns 10*. December 1991, Bath: Buro Happold.

Powerhouse::UK

Date: **1998**
Client: **British Department of Trade and Industry**
Architect: **Branson Coates Architecture,** Doug Branson, Nigel Coates, Thaishi Kanamura, Gerard O'Carroll, Rhona Waugh
Engineer: **Buro Happold, London:** Mike Cook and Ian Maddox
Consultants: **Exhibition Curator,** Claire Catterall**; Environmental Engineering,** Max Fordham
Contractor: **SHS Steel, Leeds; Clyde Canvas**
Cost: **£1 million**

The ability of the temporary building to have a significant and stimulating impact on a site upon which it would be inconceivable to erect a permanent building could not be exemplified more clearly than with the Powerhouse::UK project. This exhibition building was to have a life of just 2 weeks yet, because of its location, the potency of the image which the designers created, and the high profile of its visitors, the media attention that the project generated was out of all proportion to its duration. The event helped consummate a debate concerning the nature of contemporary British design and style dubbed 'Cool Britannia' by the media that persisted throughout the late 1990s.

Fig. 10.1 The Oyster House – a vision of the house of the future, erected as the centrepiece of the Ideal Home exhibition in London, 1998.



Nigel Coates and Doug Branson set up the architectural design practice Branson Coates in 1985 – previously both had practised as architects elsewhere and had been teachers at the Architectural Association in London. Their work shows a disregard for the boundaries of design disciplines and they pay equal attention to the interiors, graphics and communication elements of a building as to its architectural form. This philosophy has driven their practice experience which has been far more wide-ranging than most, including as well as conventional buildings, interior fit-outs, furniture design, and travelling exhibitions such as the 'Living Bridges' show which opened at the Royal Academy in 1996 before visiting Moscow and Hong Kong. The practice has completed a large number of fast-track, high-fashion shops, restaurants and bars, particularly in Tokyo where the land value is so high that buildings are sometimes perceived as comparatively low-cost ephemeral manifestations. The practice also designed the Oyster House, a temporary building though complete in every detail, that lasted for just a few days as a visionary centrepiece of the 1998 Ideal Home exhibition in London (Fig. 10.1). Their most ambitious exhibition design to date is the Body Zone for the UK Millennium Experience. This office block sized anthropomorphic structure contained an interactive audio-visual experience for the millions of visitors who visited the vast Dome at Greenwich between 1999 and 2001.

The Powerhouse::UK project resulted from a competition held in September 1997 by the British Department of Trade and Industry (DTI) to create a temporary exhibition that would symbolise and communicate Britain's strength in the creative industries. The main focus of the event was a visit by the European and Asian Heads of State during the ASAM II summit held to discuss international finance and commercial opportunities. The event would therefore be a major public showcase for British designers presented to a hugely influential group of people in the first few months of the new Labour government's administration. Prior to the competition the DTI had no firm vision of what form the exhibition structure might take or what it might contain, however, they did have the idea that it should be sited at Horseguards' Parade. This venue, situated in central London at the opposite end of St. James' Park to Buckingham Palace, is the site for the daily ritual of the Changing of the Guard and a tourist mecca in June for the world famous 'Beating the Retreat' and 'Trooping the Colour' ceremonies. The site is therefore a highly visible location that not only attracts public attention but has a recognisable image even to those who have never visited it. The high level of government authority endorsing this project meant that the usual objections that might be placed in the way of using such a high-profile, civic and quasi-military venue were swept aside.

Though Branson Coates is primarily an architectural design practice their role in this project was not restricted to this field of expertise as the contract was awarded on a 'turn-key' basis. This meant that they would not only be responsible for the design and control of the architecture, but they would also undertake its manufacture, erection and disassembly and, in addition, they would be the exhibition designers, exhibit curators and coordinators, and organise the manning and security of the event whilst it was open. To have such a degree of control is a two-edged sword – it enabled the designers to maintain a remarkable consistency in the image of the product right down to selection of the clothes worn by the exhibition hostesses; however, it also exacerbated what was already a complex logistical exercise which had to be completed in a remarkably short period of time. The commission was received on 23 December 1997, start on site was due to commence on 1 March 1998 and the opening event was to take place on 4 April 1998.

The architects' approach to the project developed from a series of notions related to two main issues – the focus of the exhibition and the nature of the site. They believed that the exhibition should not be about the placing of an object on a pedestal, and therefore should not necessarily consist of just the very best that was British-made. This could lead to the presentation of a range of already well-known names, and the reinforcement of stereotypical ideas about British design. Instead they felt the emphasis should be on the great breadth of creativity, talent, skill and original thinking that was present across a wide range of British industries. Rather than setting aside specific areas for separate specialist manufacturers, this led them to the idea of grouping areas and exhibits into four easily comprehended themes in which creativity played an important part – lifestyle, learning, communicating, networking (Fig. 10.2). They also felt that the visitor should have freedom of choice when viewing the exhibition and not be forced into a prescribed route – this idea was in tune with the multi-level, interactive exhibition strategy they wanted to develop, but also avoided one of the biggest problems of consecutively viewed exhibi-

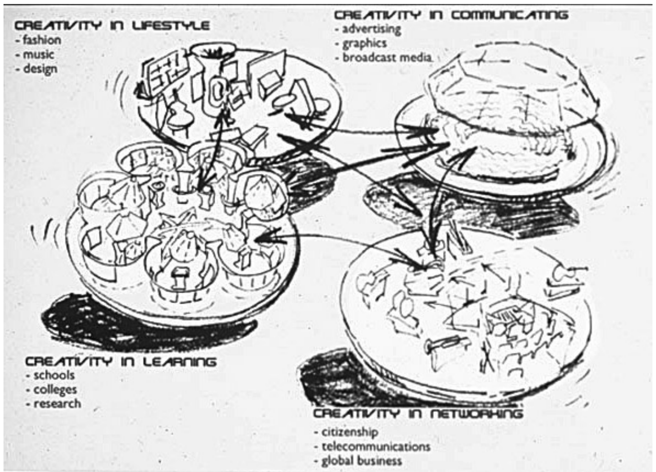


Fig. 10.2 Exhibition layout concept.

Fig. 10.3 Bath International Music Festival temporary tent

tions which is the queue that builds up behind the slowest group of visitors as they pass through.

The designers were aware of the profoundly formal presence of the site, conventional, imposing, and static, and it was their desire from the beginning to respond to this character, though in a form that expressed the ephemeral nature and purpose of their temporary intervention. They had also perceived the exhibition circulation pattern as a 'crossing' with an entry strategy that led visitors directly into the building's centre from which they could enter any of four zones, at any time and in any order. This naturally led to a symmetrical layout focused on the four zones divided by a circulation route, a planning strategy which reflected their experience with two earlier building designs. In 1995 Nigel Coates designed a temporary tent structure for the Bath International Music Festival to be sited in the city's oldest open green space, Sydney Gardens (Fig. 10.3). The building defined a crossroads, and had a plan and three-dimensional form that was split into four segments. A tensile membrane roof form, designed in coordination with Buro Happold, created an evocative sensuous image that transferred this form into three dimensions. More recently the practice has been immersed in the design of the National Centre for Popular Music in Sheffield, a 4500 square metre, £8 million permanent exhibition and performance building. Their research into the way visitors would use this building was used to generate ideas for Powerhouse::UK.

Though Branson Coates won the competition primarily on their concepts for the exhibition character and the building form, their success was also influenced by their investigation of technical strategies that would enable the project to be positioned on the DTI's preferred site. Any building situated in Horseguards' would have to have two important physical constraints – it would have to be built without conventional foundations or other constructional interventions in the parade ground surface, and it would have to be removed within 3 days of the exhibition closing. The DTI had considered the possibility of using commercially available temporary building systems, however Branson Coates deemed this approach unacceptable owing to the, at best, prosaic image that such structures convey – if the exhibition was to have the desired impact it must be a designed object in all ways, including shelter and organisation. The limited duration of the exhibition also led to the idea that it might not just be temporary but also capable of being reused at a later date on other sites. For these reasons, the early explorations of building structure and construction methods were based around this concept of a building that could be placed on Horseguards' initially but might then be moved elsewhere, for example to a garden or to the top of a multi-storey car park. The enclosure should therefore be lightweight, easily demountable, and have a unified non-directional elevational treatment with entry possible from all sides. The overall image should be for a definitive, self-contained, mobile entity (Figure 10.4).

Branson Coates' initial response was for an inflatable building that used pneumatics for both superstructure and skin; however, the lead-in time of just 3 months from the design commission until opening day meant that, though a pneumatically

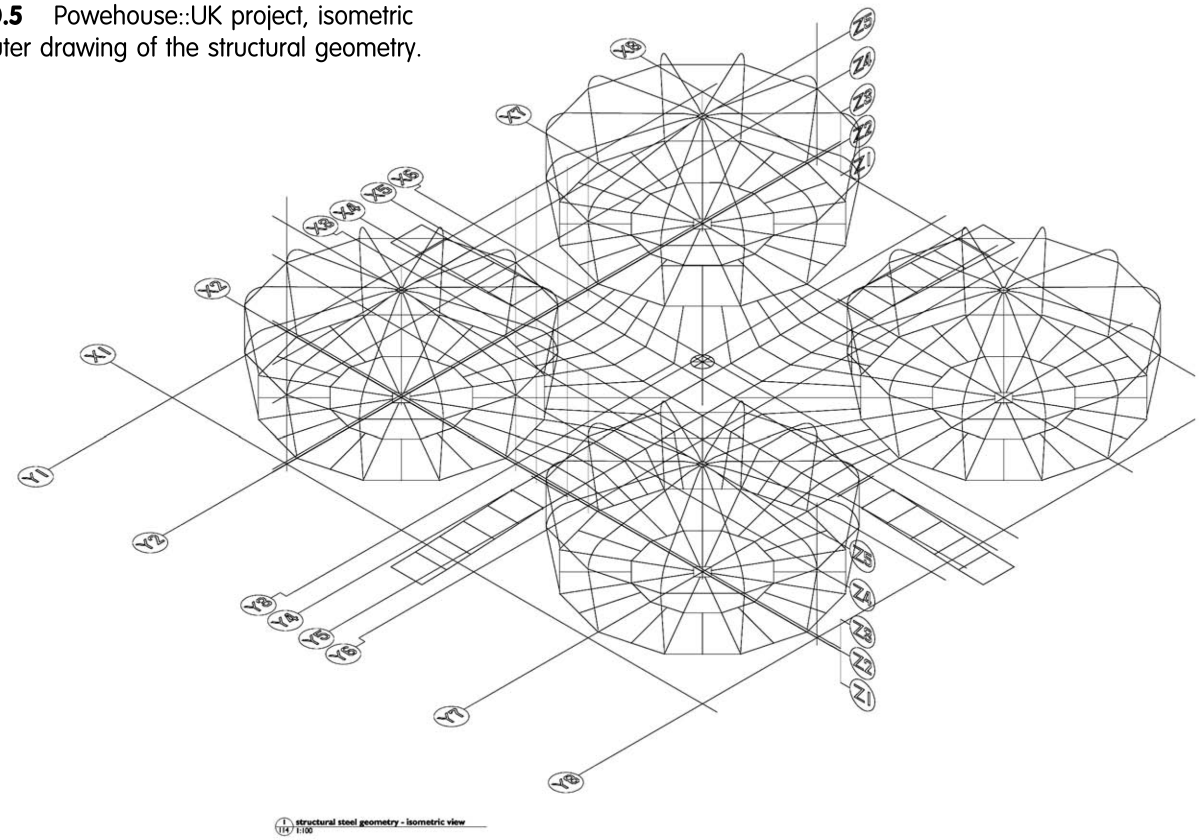
Fig. 10.4 Powerhouse::UK – a self-contained ephemeral image that acts as a foil to the surrounding buildings.

supported envelope could be designed, and it could also be built, there would be no time to make any prototypes. The design work would be totally reliant on the calculations provided by Buro Happold and prototyping that had already occurred for other projects with different design parameters such as the work done for the US Army mobile shelters (see Case Study 12c). Despite their enthusiasm for the pneumatic structure approach and their conviction that it could be made to work given the time to prove it, the architects decided that the risk of creating an ambitious structure without physical testing was too great, and moved from the concept of the inflatable structure doing two jobs (structure and skin) to the more simple one of letting it do just one (skin alone). To do this would still provide them with the image they sought, reduce the erection and dismantling time compared with a rigid system and also, because of this cladding method's lightweight nature, it would mean that the supporting structure could be small in both weight and section (Fig. 10.5). The adoption of the steel frame concept also possessed other advantages – it meant that the building design would have a much easier passage through the constructional and safety regulations in the restricted time that was available, and it would form a framework for dispersing lighting and other services. A simple steel frame system was devised that used standard rectangular sections for speed of manufacture and simple key-operated dry joints to allow ease of erection (Fig. 10.6). The four 16-metre diameter drums were clad in a silver-coated polyester PVC membrane, connected to the frame with extruded aluminium sections. The pockets of the membrane were inflated with a single low-power electric fan (Fig. 10.7). Valves were fitted in the membrane to avoid the risks of over-inflation. In the case of failure a back-up fan was installed, though this was never used – if the main fan was switched off it took 4 hours before the membrane became visibly limp. The central circulation section was covered with a conventional tensile membrane formed into a double curved pattern that would maintain its shape and rigidity and resist wind and rain loads. A feature of large-scale relatively lightweight temporary buildings is that foundations, rather than primarily being used for supporting the structure's weight, are used for holding the building down in response to wind loads. As conventional foundations would not be allowed on Horseguards' Parade, the exhibition building was restrained by the weight of four mass concrete elements, the entrance ramps.

The architectural image was intended to be fun, exciting and innovative – it was not intended to express an architectural position (e.g. functional, ecological, industrial) but to be a marker in the city, a presence which would attract people and stimulate their curiosity. Pressures on the design development enforced by time restraints meant that Powerhouse::UK could no longer be an instant building concept; however, the end result would still be a reusable structure.

The contract was let under simple letters of agreement which stated a fixed price for a fixed proposal on an agreed delivery date. The architects received enquiries from many contractors interested in working on the project; however, most were not interested in building what the architect had designed but instead offered their own preferred

Fig. 10.5 Powehouse::UK project, isometric computer drawing of the structural geometry.



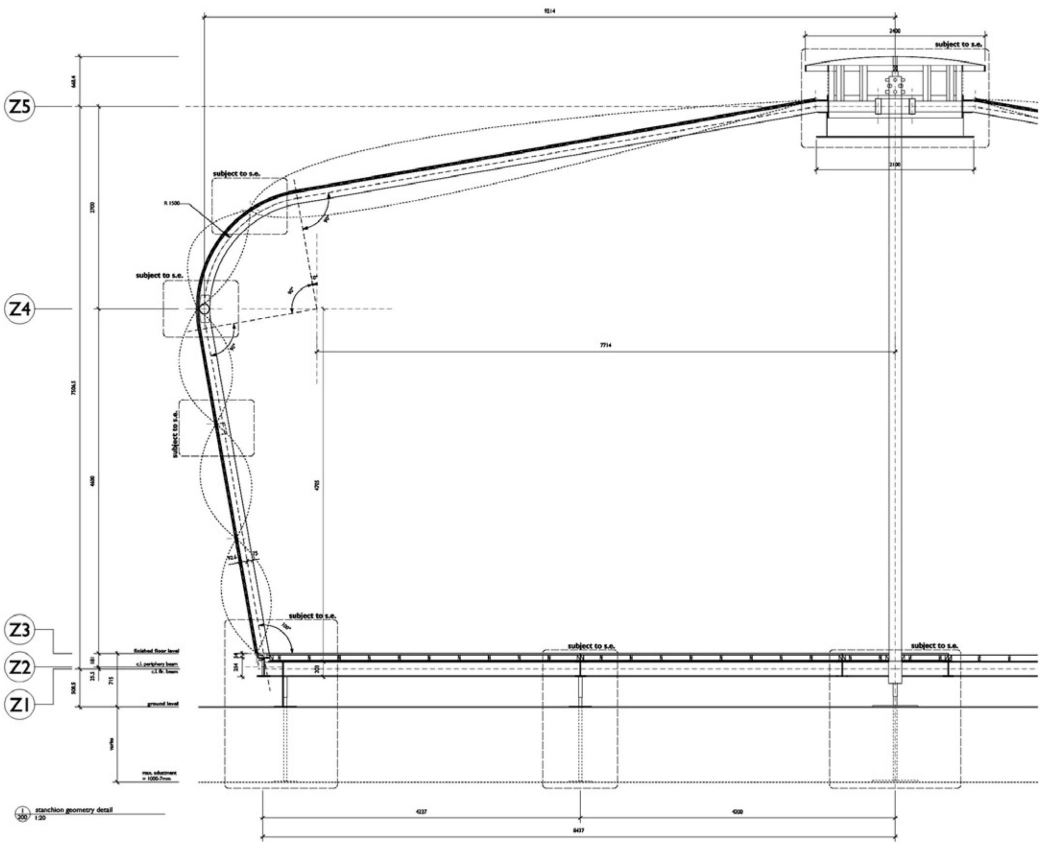


Fig. 10.6 Detailed section.

CASE STUDY 10

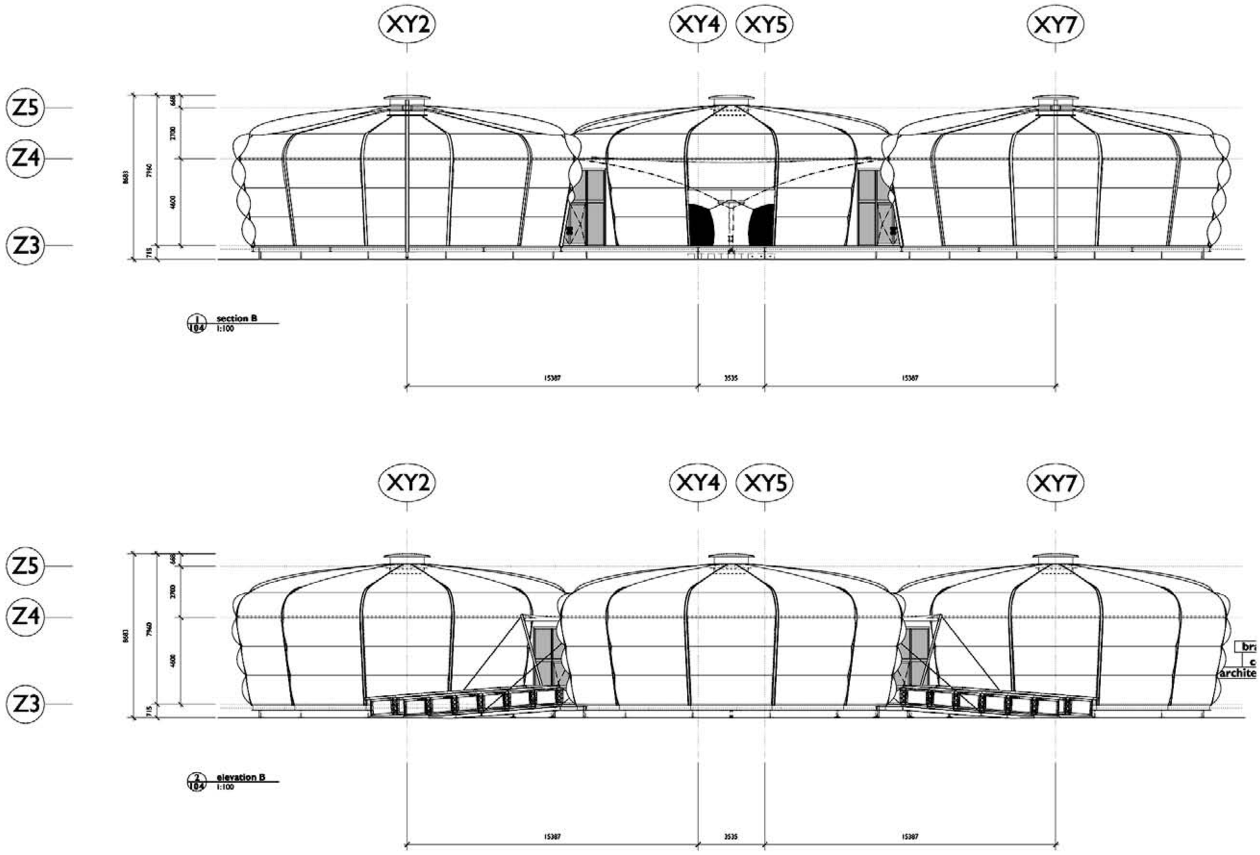


Fig. 10.7 Section and elevation.

solutions, including the reuse of completely different building structures left over from previous projects. The two most important contractors were SHS Steel and Clyde Canvas who, respectively, made the frame and the skin. Significantly, these contractors had worked together before and an interactive working relationship between builder and consultant became established early on, an essential element in the creation of a unique building under the additional burden of an incredibly light design and construction programme. Specialist exhibition contractors were employed to make and install the flooring, staging and lighting systems. During the work on site, the steelwork went ahead of schedule and an opportunity to move ahead of programme was thwarted by the impossibility of bringing the membrane delivery forward. However, the building and exhibition were completed exactly on schedule, fulfilling a tight, though intricately predicted programme. Each element of the building process was worked through with contractors prior to site operations commencing, but even so the designers made visits at least twice a day during the intense construction period, the frequency of these visits also a result of the nature of the turn-key operation to which the practice were committed. The most crucial point in the programme was the completion of the envelope's weatherproofing, as all the exhibits were set to arrive in relation to this date. The formal strategy of a simple building form with separate discrete elements responded well to this complex programme – allowing pre-manufactured components to be used almost exclusively, and installation time to therefore be kept to a minimum.

The client was pleased with the final result – the building was available on time, successful in use and helped create a significant part of the publicity which was necessary to make the event a success. The building's conception as one component in a balanced holistic programme that celebrated the exhibits it contained, rather than overshadowing them, was crucial in this regard. Though it was designed to make an impact on a

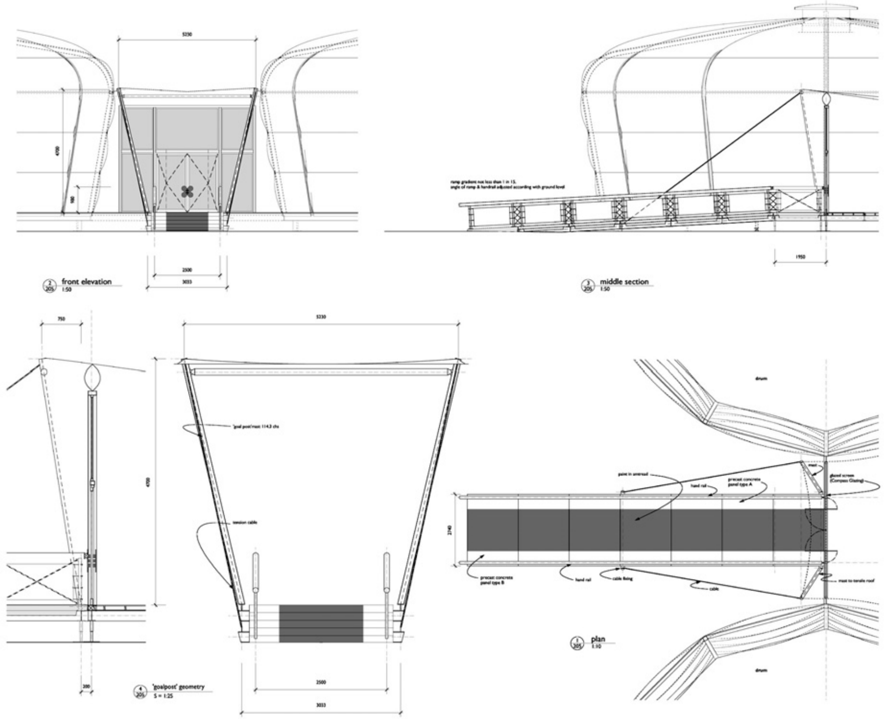


Fig. 10.8 Entranceway, ramp and handrail detail.

Fig. 10.9 Entranceway at night.

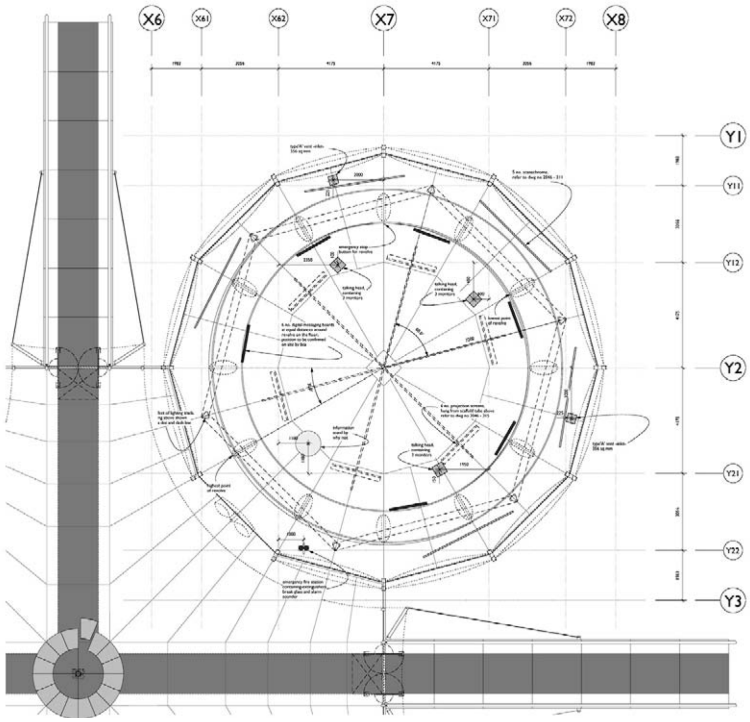


Fig. 10.10 'Lifestyle' exhibition plan.

Fig. 10.11 Powerhouse::UK exhibition interior.

powerful few, Branson Coates felt strongly that the exhibition should also be an event open to all. The DTI supported this view and initially the exhibition was intended to be free to the public after the ASEM II summit was over. However, fears that the exhibition might be assailed by numbers of visitors it was not designed to handle and criticism levelled at the organisers that they had not made sufficient attempts to offset the exhibition's cost, led to the introduction of ticket charges and restricted entry procedures. This had a profound effect on the original circulation intentions as entry and exit became restricted to just one of the ramps, subverting in part the designers' free-flowing concept that had proved popular with the client (Fig. 10.12). The exhibition also took place at a time when increased security became an issue, thereby highlighting one of the problems of integrating temporary event structures into the existing urban infrastructure – the relationship with statutory, government and civil authorities. Security advisers insisted that a standard concrete-based, galvanised metal fence surround the entire building, compromising the designers' intentions to create a wholly designed environment though, significantly, the Prime Minister's office insisted the fence was removed for the main public and media events.

No significant problems were experienced in the erection of the building. Minor problems were able to be fixed without affecting the programme or the cost. For example, four minor leaks in the membrane were easily fixed in situ. There are, however, a number of design modifications that the designers would like to introduce to ease deployment for future events. Unanticipated flexing in the concrete ramps (surprising for a 14 tonne monolithic element) occurred when the roof tie-down cables, to which they were connected, were fully tensioned. Though not a problem in itself, it meant that the handrails had to be reset as these also flexed. When the building was dismantled, wind loads on the skin had also caused the steel frame to twist, stiffening the dry joints. In some cases considerable force was needed to move the joints back into their original position to allow them to be disconnected. More significant is the fact that the constricted programme development period, though not affecting unduly the final image or operation of the building, did compromise the possibilities for its technical performance, and these have in turn affected its viability for reuse. Constraints on the time available for design and manufacturing led to the expedient choice of a steel frame and concrete ballasting. Similarly, time restrictions made it impossible to create an economic modular floor system for the complex building footprint and a one-off disposable system was used. Though the building can be taken down in 3 days, erection in its current form would take much longer – 3 weeks – and would also require significant investment in non-reusable elements. There have been many requests by a wide variety of organisations to utilise the building for a temporary event; however, to date none has yet come to fruition, owing to the request coming too late, or the funds required to underwrite its installation not being available. To make the building more easily

Fig. 10.12 Central reception/information/circulation space.

Fig. 10.13 An identifiable address for a temporary building.

Fig. 10.14 Assembly sequence taken from a time-lapse video.

deployable a new foundation would need to be made – perhaps using water ballast – a new floor system manufactured, and minor modifications made to the frame jointing and bracing. Such modifications would seem to be economically viable, as the result would be to introduce an extended life to a structure that has already fulfilled its primary role successfully.

To design, manufacture, erect, curate, and administer such an event in just 3 months is a remarkable feat; however, with a greater lead-in time the long-term reusable life of the building that was a main part of the project would have been assured. That the potential of the building in this area has yet to be proven is outside the control of Branson Coates whose commission was to design a temporary exhibition, not a portable building. The architects perceived the possibilities to make this a portable building but felt, probably correctly, that their duty to their client was primarily to bring in on time and on budget the specific exhibition which was the focus of the commission. Pursuing the issues that would lead to a more technically efficient reusable structure probably would, at the time, have compromised this objective. Despite the undoubted enlightenment and enthusiasm of the

DTI as a client in the post-competition phase of this project, it is clear that if they had been aware beforehand of the extended possibilities that the commissioning of not just a temporary exhibition, but also of a portable building might bring, Powerhouse::UK's evocative presence would have been ensured at other venues around the world besides Horseguards' Parade.

Further reading

'Beating the Big Blue Drum for Britain', *Evening Standard*, 17 February 1998, p.18.

'Dramatic Arts – From Avante Garde to Old Guard, Two Recent Projects Profiled', *Light*, July 1998, pp. 36–37

Elliot, Valerie. 'Banging the Drum for Cool Britannia', *The Times*, 9 March 1998, pp.1, 7.

'Future Tense – Nigel Coates' Design for Bath Festival Tent', *Design Week*, 12 May 1995.

Gibson, Grant. 'Designers Power Up', *FX*, April 1998, p. 15.

Kronenburg, Robert. 'Branson Coates Architecture, Powerhouse::UK', in Ephemeral Portable Architecture, themed edition of *Architectural Design*, Sept/Oct 1998, pp. 88–93.

Moore, Rowan, 'Welcome to Cool Britannia', *Evening Standard*, 27 March 1998, p. 11.

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Markies, Almere, Netherlands

Date: **1986–95**

Client: **Böhtlingk Architectenbureau**

Architect: **Eduard Böhtlingk**

Contractor: **Superstructure: van den Born, Carrosserie b.v., Waalwijk;** Awnings construction: **Mado Nederland b.v., Eindhoven; Furnishings: meubelmakerij Lomans, Rotterdam;** Metalwork installation: **technisch buro Dreissen, Rotterdam.**

Cost: **45,000 Euros**

Eduard Böhtlingk practises architecture from a small studio adjacent to his house, set in a quiet canal side-street in the village of Maasland, near Rotterdam in the Netherlands. The house has been converted to its hybrid use in a quiet and sensitive manner – there are few signs that this is anything other than a typical semi-urban Dutch home. Böhtlingk remarks that his architect friends with offices in the big cities of Europe make fun of him for living and working where he does. He makes no comment – there is no need to because when one understands his design ambitions, and the process he employs to address them, it becomes clear. Just as living and working in a village is not the usual base for the creation of architecture, Böhtlingk's approach to design is not usual either. He compares his creative stance to that of an inventor – he first likes to discover a strong idea and then realise it through persistent, dedicated detail design in direct response to the function it must satisfy. This approach may sound like the dominant focus is on the pragmatic, but it is not. The 'strong idea' is an inspirational creative act that provides each project with its uniquely inspired identity. Böhtlingk's architecture is well-mannered, and at first glance it may also appear to be conventional. However, in all his work, but particularly his work concerned with mobility, he questions fundamental attitudes to the typical design and building strategies utilised in the developed world.

CASE STUDY 11

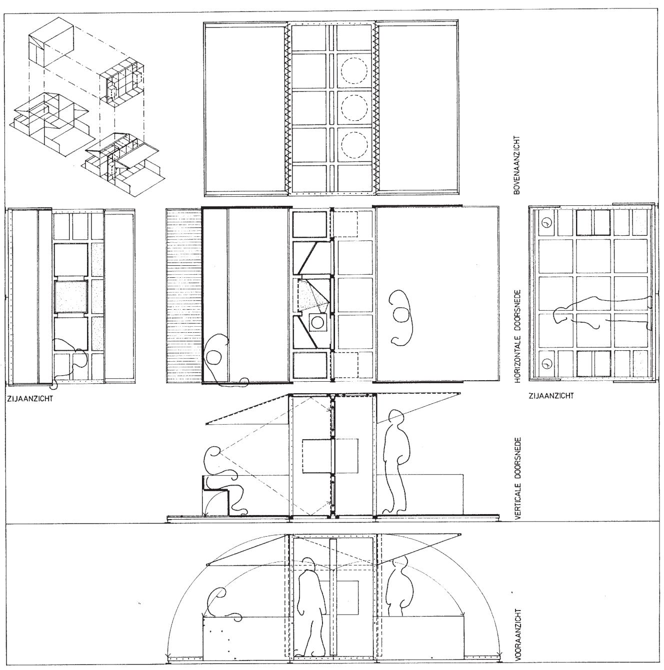

Fig. 11.1 Young Architects Biennial Exhibition: design drawing.

The work of Böhtlingk Architectenbureau is divided into two discrete areas: fixed work and mobile work. The fixed work is diverse in building type – housing, education, industry, public buildings. The mobile work is equally diverse and includes an exhibition, a dwelling, a landscape feature, and a housing design system. All these mobile projects have emerged in response to architectural design competitions. It is probable that a major factor in Böhtlingk's success at winning competitions for mobile structures is in the manner in which he addresses the problem – by the development of a strong conceptual approach that is then explored through dedicated detailed design work. This approach is also recognisable in his fixed work, though because other considerations such as sensitivity to existing site conditions or urban form take precedence, the buildings do not shout their innovation in flashy façades but whisper it in visual clues and ingenious planning.

Eduard Böhtlingk studied architecture at the Technical University of Delft, and amongst his professors was Tjeerd Dijkstra who later became the Chief Architect for the Netherlands Government. In 1982 Böhtlingk's newly formed independent practice was commissioned by Dijkstra to build a new office building in Oud-Beijerland. He conceived a completely flexible façade that could be altered by unclicking aluminium frames from a sub-system – a flexibility which has been used in the intervening years to make changes in the way the building is used. His practice has since completed many buildings in the Netherlands – in fact, it is this 'fixed' work that has supported the continuous experimentation with 'mobile' design, even funding the construction of his most significant project, the 'Markies'.

Böhtlingk's first mobile project was completed in 1985. It is a direct development of his belief that furniture design may be interpreted and designed as small-scale constructed architecture. Ten practices were selected to each create a mobile exhibition for the Young Dutch Architects Biennial to be held initially in the Beurs van Berlage in Amsterdam. Each team was invited to design a mobile exhibition structure in which to display their work. Several of today's major practices took part including Mecanoo and Raoul Bunschoten. Böhtlingk conceived his exhibit as a protective, light-weight, steel framed plywood container

Fig. 11.2 Young Architects Biennial Exhibition on site in the Beurs van Berlage, Amsterdam. (Photography by Ger van der Vlugt)

which, once it arrived at its location, would fold out to reveal the display of his work within. Two separate zones were created by unfolding walls – a seated slide show viewing area with a bench that pulled out from the floor and a standing area for viewing drawings. The entire unit could be collapsed into a volume one third of its extended size in just a few moments. It is interesting that although the Biennial was intended to be relocated to other venues this never happened because most of the other exhibits were difficult to move.

In 1986, Böhtlingk entered the 'Temporary Living' based on a site in Almere, Netherlands. Organised by the Fantasy Foundation of Almere to stimulate new building ideas for this new polder, an area of land reclaimed from the IJsselmeer, the competition's objective was to explore the potential for building temporary houses on sites unsuitable for long-term occupation. A semi-rural site for seventeen houses in Almere was given temporary planning permission as a nearby busy road was thought to make it unsuitable for permanent dwellings. The prize for each of the successful entrants was the use of the site for five years and 4500 guilders (approximately 2000 Euros) towards the cost of construction. Böhtlingk's concept was to build something portable instead of something temporary. A temporary house, even if built from fully recyclable materials, would result in wasted energy, whereas a portable dwelling could simply be re-sited. Though he was the only designer to take such an approach, his entry was chosen to be one of the seventeen winners. Although the design was one of the smallest buildings, it has been one of the longest to reach completion, taking ten years of painstaking effort to be realised. The Markies is named after the Dutch word for the movable fabric awnings used to protect windows from the sun – it is also a play on the theme of royalty suggested by the word 'marquis'. This name suggests a simple

Fig. 11.3 The 'Temporary Living' competition site in Almere.

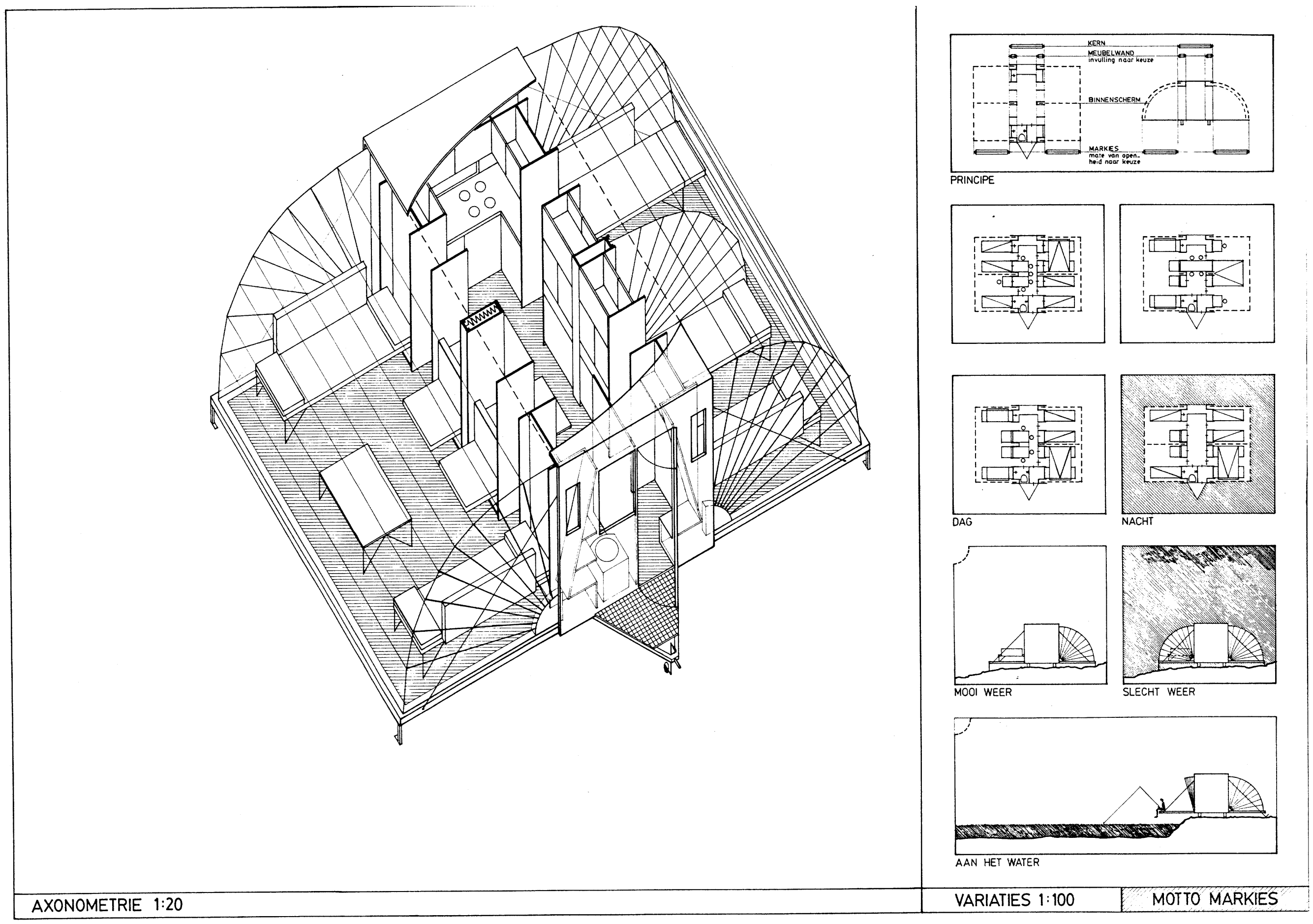

Fig. 11.4 Markies: competition entry drawings.

shelter but one of very high quality – a concise and accurate description of the design ambitions for the project.

When preparing his submission for the competition Böhtlingk realised that he must not only convey the simplicity of his idea, but also the quality and the depth of detail that would be an important part of its realisation. In selecting his design to be one of the winners the judges recognised and praised this aspect of the entry describing it as 'exceptionally clever and lucidly drawn'. As a result the drawings which were prepared in 1986 are remarkably similar in almost every detail to the completed building.

Böhtlingk makes it clear that the intention of the Markies was not to be a caravan or travel trailer but a real mobile dwelling. When his family go camping they prefer to stay in a tent – to be close to nature and to enjoy the specific environment of being outside. Tow-able caravans are designed to be capsules containing amenities for comfort and shelter. Although some very expensive models have small push-out volumes in sleeping and living areas, the user is primarily contained within the linear space of the vehicle – it is only the awning that extends this space out into the landscape. The Markies is completely mobile but not intended for daily towing from place to place. It is a real dwelling that is as comfortable as a permanent home, but with three important additional features: it can be moved to a new site easily; it contains all its furniture and fittings as integral parts of the structure; and it retains close contact with the environment in which it is situated. The building was designed with the competition site in Almere in mind – it has a rural aspect adjacent to a canal but also has mains services and road access. However, as with so many mobile buildings this was only identified as a typical site – the Markies actually works at a wide range of different types of sites.

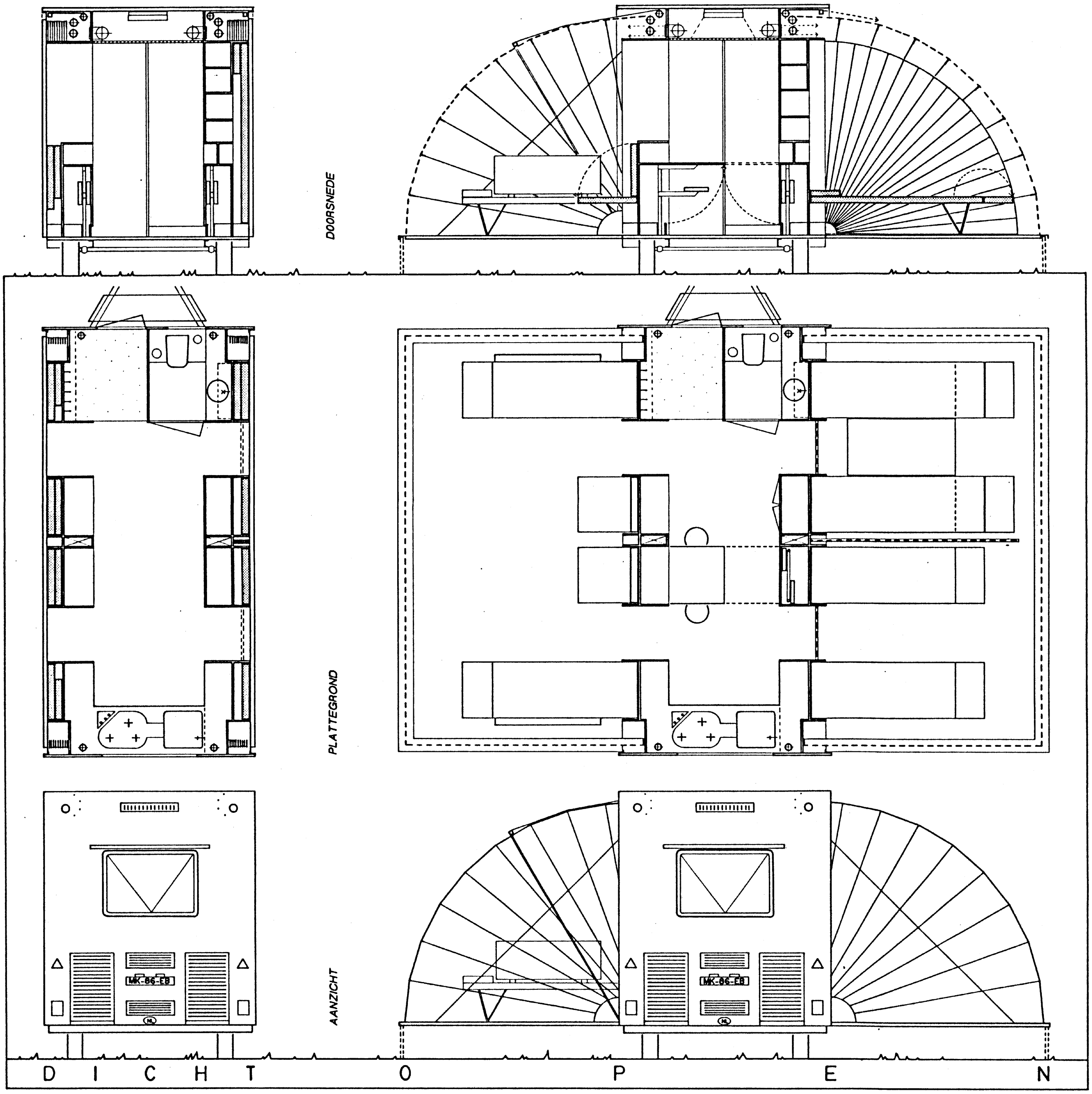

Fig. 11.5 Markies: detail drawing of final version.

The transportation dimensions of the structure are 4.5 metres by 2.2 metres, however, the floor area is tripled when the side panels are dropped to their deployed position increasing the width of the dwelling to 6.6 metres. Entry, with a small hallway and coats store, is at the end adjacent to the towing hitch. The dining and cooking area contains all the storage compartments. To the left of the entry is the integrated shower room and WC. All these primary facilities are built directly onto the Markies' main chassis and they can be accessed whilst the side floors remain in their travelling position. The fold-down area to the left of the entrance has two bedrooms, each with its own door. The area to the right is the living space. All the furniture is specially designed and manufactured and forms part of the

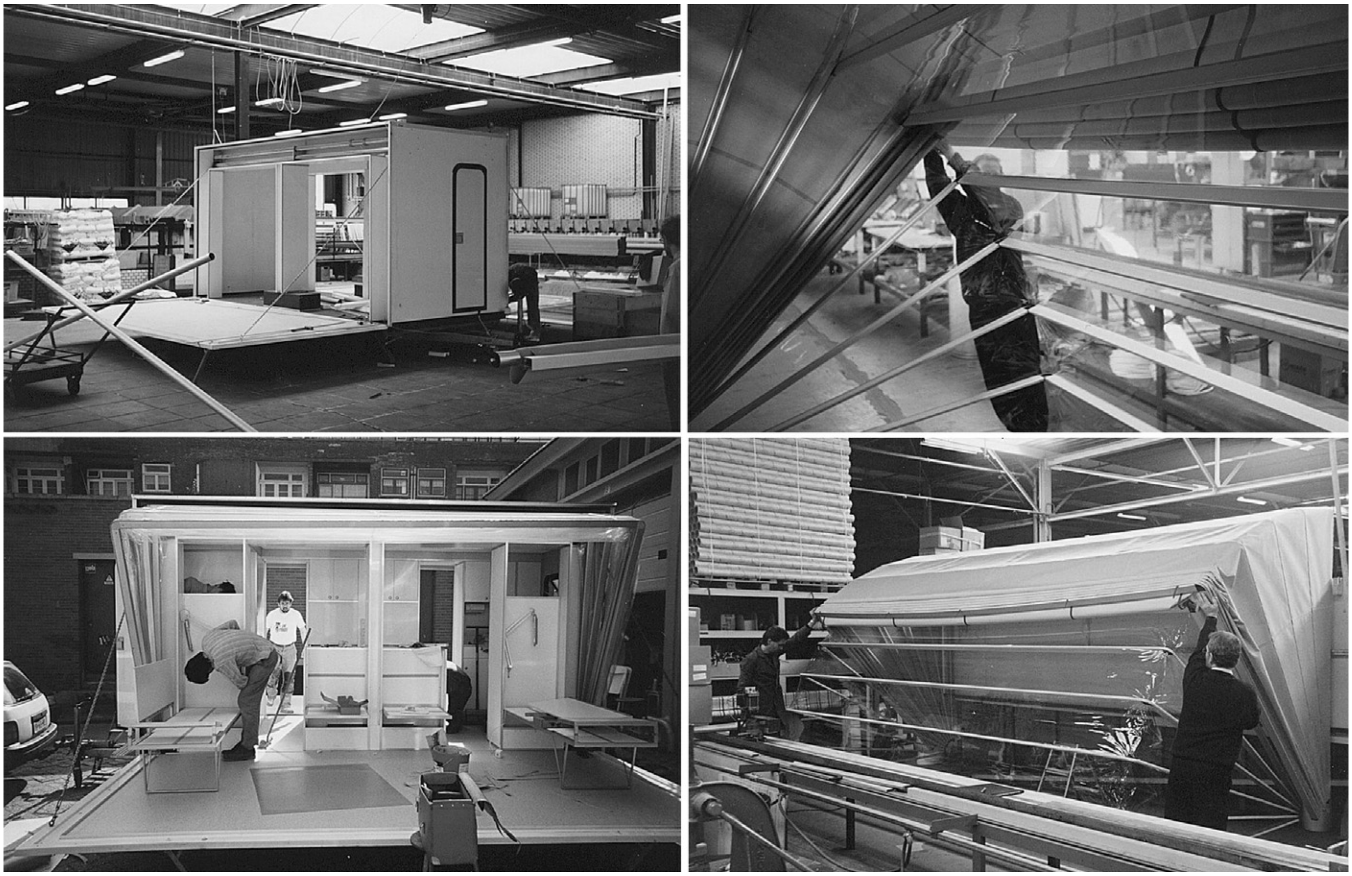

Fig. 11.6 Markies: construction photographs.

building's structure. The dining table folds down from a storage area, dining stools swing out from beneath. Living area chairs and settees fold down from the walls. The four beds also fold down, each revealing a wardrobe recess.

After the competition, Böhtlingk set about finding a sponsor to help pay for and build the Markies. As he had designed a product which he believed possessed easily understood commercial precedents combined with a realisable construction strategy, he imagined that it would not be difficult to find organisations who would recognise the design's commercial potential and wish to become involved in its realisation. However, this was not the case. Though many manufacturers were full of praise for his design they were unwilling to risk capital on developing it as a product. There was an inherent conflict between Böhtlingk's belief that building the product for the first time had to be done at a high quality. His view was that you did not have to prove the concept – that was already clear – but you did have to prove that it worked and that it worked well. Whilst continuing with his 'fixed' architectural practice work he continued to search for and meet with potential sponsors. It was suggested many times that in order to get it built he should compromise and build it cheaply, but Böhtlingk believed that this would have the effect of preventing future potential – people would not see the mobility or any of the other features of the design, they would just see the cheapness.

In 1991 Böhtlingk came to the conclusion that the only way he would get the Markies built to the standard he required was to pay for it himself. Consequently, he completely revised his construction strategy, beginning the search for materials, builders and manufacturers who could assist with the project over a staged period as funds allowed. He divided the construction process into three distinct parts: the chassis, walls, floor and roof; the sunscreen and deploying mechanisms; the built-in furniture and interiors. Beginning in 1992 on the conventional standard steel chassis and towing assembly (a gift from mobile site-hut manufacturers de Meeuw), the superstructure was made by coach-builders van den Born. For the main struc-

ture Böhtlingk had to find a system that was both strong and comparatively light. Though both sides of the building fold down they would provide useful rigidity during transportation; however, the structure must of course also remain rigid when unfolded at the site. He chose a hybrid system of 30 mm polyester coated Multiplex sandwich panels strengthened at the edges with bonded steel or aluminium sections. The panels consisted of 1.5 mm polyester, 4 mm multiplex, 19 mm polyurethane, 4 mm multiplex and 1.5 mm polyester. The main core of the building was formed of these panels which were glued and screwed together and also as a unit to the separately made steel chassis. A key feature of the Markies design is its easy conversion from mobile to static configuration, and so it was essential that as many elements of this process as possible were completely automatic. Consequently, Böhtlingk decided that all substantial movable elements of the structure must be motor operated by the touch of a button. The side panels that become the main cantilevered floors when unfolded are suspended from steel counter-weighted chains which are winched in and out by an electric motor. The awnings are also electrically operated, this time on rollers, and were made by the specialist sunscreen and awnings manufacturer Mado. The main awning on the living area side is 1mm thick transparent PVC, though there is a secondary screen which is used as a sun-blind or for privacy. On the sleeping area side the awning and the sunscreen were made from opaque Ten Cate technical fabric of a 50% polyester/cotton weave. The fold down fabric divider between the two 'bedrooms' was made of Luxaflex Duette braced with aluminium strips. All the awnings and sunscreens can be pulled down to any desired position. The aluminium framework of the awnings was specially designed to be strong but also to be flat-packed into a tight space for transportation. The awnings were the only part of the Markies to be sponsored, and have subsequently been used for publicity purposes by the manufacturer.

Building the furniture was an especially complex task. It was important that all the furnishing elements could be folded into the structure of the building, be light and extremely compact, but

Fig. 11.7 Markies: unfolding sequence (photograph by Roos Aldershoff).

Fig. 11.8 Markies: interior photograph of the kitchen/dining area – the living area is to the right and the sleeping area to the left (photograph by Roos Aldershoff).

also be able to survive the demands of a growing family. The panels were made of 15 mm thick Poplar Multiplex with vinyl or synthetic resin coatings. In some cases where extra strength was required (for example the beds and seats) a hollow rectangular section steel frame was made to support the panel system. A metal worker and a furniture maker were employed to make the separate components before assembly into the structure took place. The building is serviced by plugging it into mains supplies similar to those found at a touring caravan site, there are no water tanks or batteries in the prototype. However, the design is flexible enough to make it completely independent if more remote sites become a part of the brief for future versions.

The Markies has two distinct forms – mobile and static. When it is mobile it is anonymous, an unremarkable travelling object. When it is deployed into its static configuration it turns into a completely different object with a number of obvious connotations associated with tents and caravans but also with accordions, prams and butterflies! It is this last image that stays in the mind, because the changing process is so natural and effortless – like a butterfly unfolding its wings. The building is unhitched from the tow vehicle in the required position, services are connected, the entry door opened and the button pressed to fold down the side panels to form the living areas. Other buttons are pressed to lower the awnings and then chairs and beds are dropped or swung into position. The whole process takes moments. No advanced technology has been used in the creation of the Markies, and this is really not the point – what is impressive is the simplicity and the quality of its operation and design. All the operating elements work in an effortless way. There are no superfluous features or gadgets. The choice of, and relationship between, the individual components that have been brought together to make the entire

Fig. 11.9 The Markies on mass-market television.

dwelling workable seems to be inevitable. This is not a project whose worth rests on dramatic innovative technology but on quality of concept and execution. However, it does grab the imagination...

Once the Markies became a reality, public appreciation of it changed. In 1996 it won first prize in the public's choice of the Rotterdam Design Prize, a widely publicised national design competition which was the first event to establish it as a practically achievable product. It has subsequently been published widely in national and international press. It has featured on television both in mass culture popular shows and in specialist design magazines and is in demand for exhibitions and events that range from the Vitra Design Museum's touring exhibition '*Living in Motion*' to the annual Camping and Caravanning Fair in Amsterdam. Böhtlingk makes the point that the Markies is not a design object that is set within prescribed boundaries – it is appreciated by both the general public and design professionals. This is because it fulfils two distinct criteria that do not frequently occur simultaneously in the same object – it is both a good product and it is a good design. The Markies, when not employed in its touring promotional role, is still used as a family holiday home on the site at Almere. Of the seventeen plots, thirteen are now occupied by buildings resulting from the 1986 competition and four from a subsequent second round. Though initially intended as a temporary development, public interest has been so high that the development has become a permanent one.

Böhtlingk is now working towards the development of a mass-production Markies that will differ from the original in a number of ways. The prototype weighs 2500 kg, twice the weight of a small caravan and heavier than is practical for towing by a family car. The mass-production model will therefore be lighter and perhaps also smaller if neccessary. Other differences are that the fold-down side panels may be operated by hydraulics, and internal corners will be rounded. The proposed manufacturing strategy is to make the first '0' series Markies for twenty customers who will have extensive after-sales care. This project is to be a collaboration between the awnings manufacturer who was the prototype's only sponsor and a conventional caravan manufacturer. Böhtlingk estimates that the Markies project has so far cost him about 45,000 Euros in design time and manufacture costs. The most recent estimate of the cost of the mass-production Markies is 20,000 Euros.

During the decade-long gestation period of the Markies, Böhtlingk has continued to explore the concept of mobile structures. In 1990 he achieved the distinction of perhaps being the first architect to win a competition by fax, creating a light-hearted design for a dwelling based on the form of Aldo Rossi's famous coffee pot La Cupola in a competition organised by the architectural journal *Architectuur and Bouwen*. Böhtlingk also used a

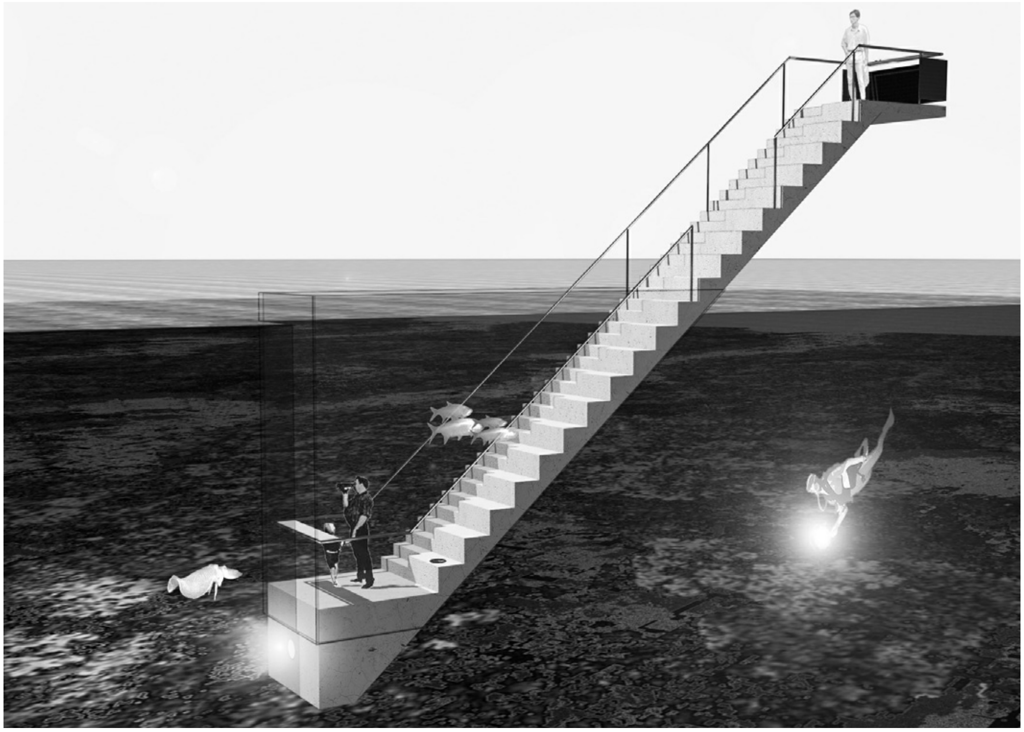

Fig. 11.10 Spotter: photomontage.

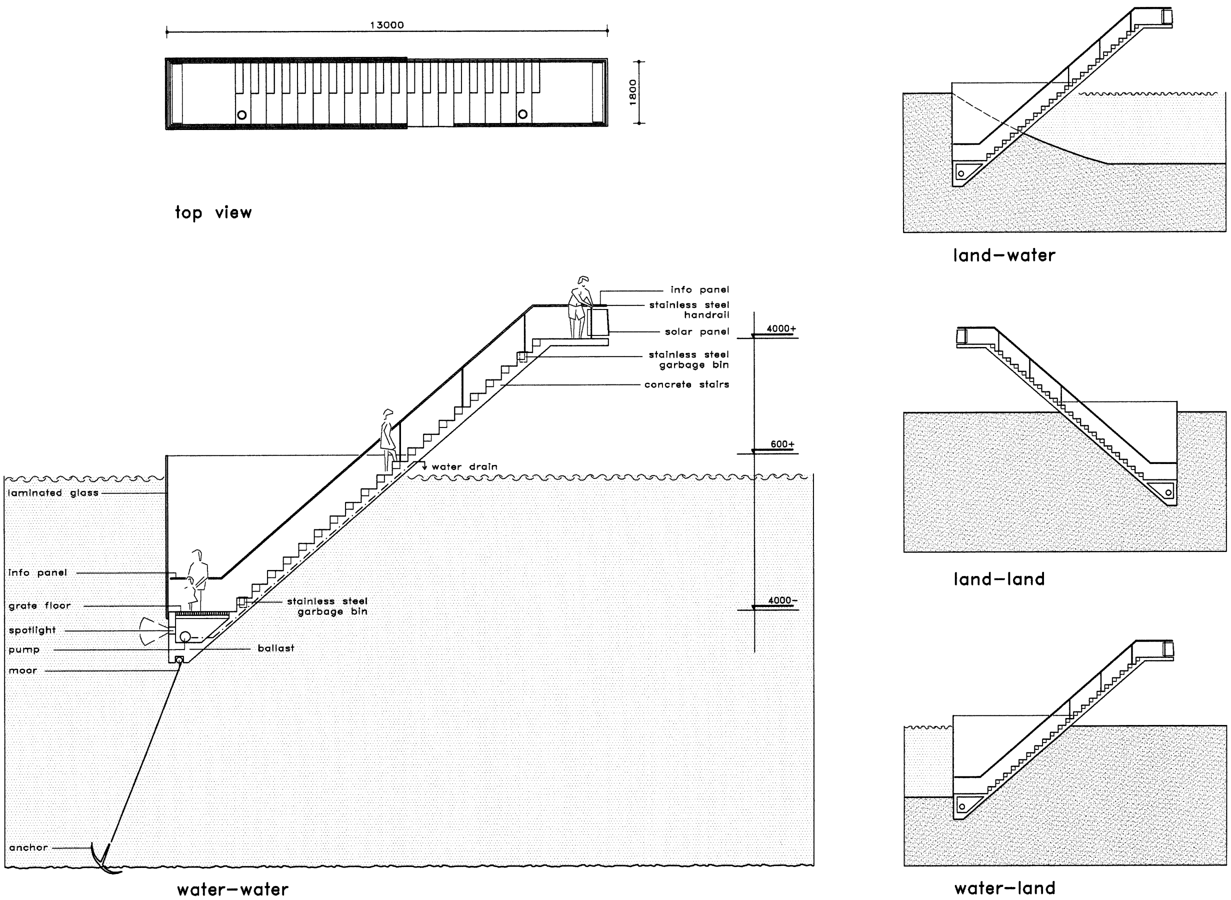

Fig. 11.11 Spotter: plans.

mobile concept to win the 2000 competition to design a new under and over water observation point held by the National Park Oosterschelde in the Zeeland estuary in the south Netherlands. This radical concept was to create a mobile floating platform consisting of a staircase that mysteriously disappears beneath the water's surface. The design consists of a single set of reinforced concrete steps with a small platform at each end. The underwater platform is 6 metres below the surface protected by a thick glass wall which displaces sufficient liquid to make this bottom part perform like the hull of a boat. The top platform is elevated 4 metres above the surface of the water providing an outstanding view of the surrounding water and landscape. Lights below water level illuminate the submarine environment and a pump and submerged ballast ensure the platform remains in balance. Though this structure is based on the well-tested phenomenon that lowering the centre-of-gravity of a marine vessel provides it with an inherently stable platform, construction funds have yet to be released to build a prototype.

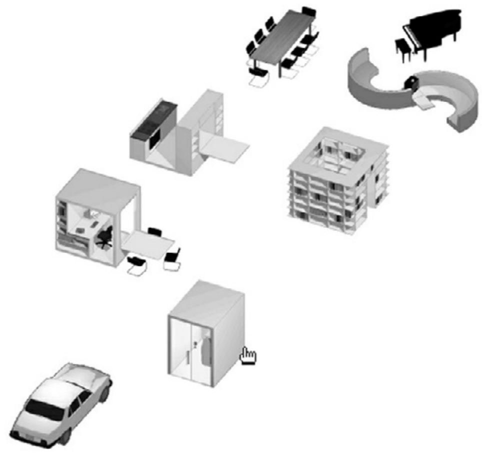

Fig. 11.12 Mobile Unity – a selection of 'furniture' elements.

Böhtlingk's latest mobile design has also been developed from a competition project though in this case his entry did not win because the judges, in his words 'just did not get it'. The Mobile Unity

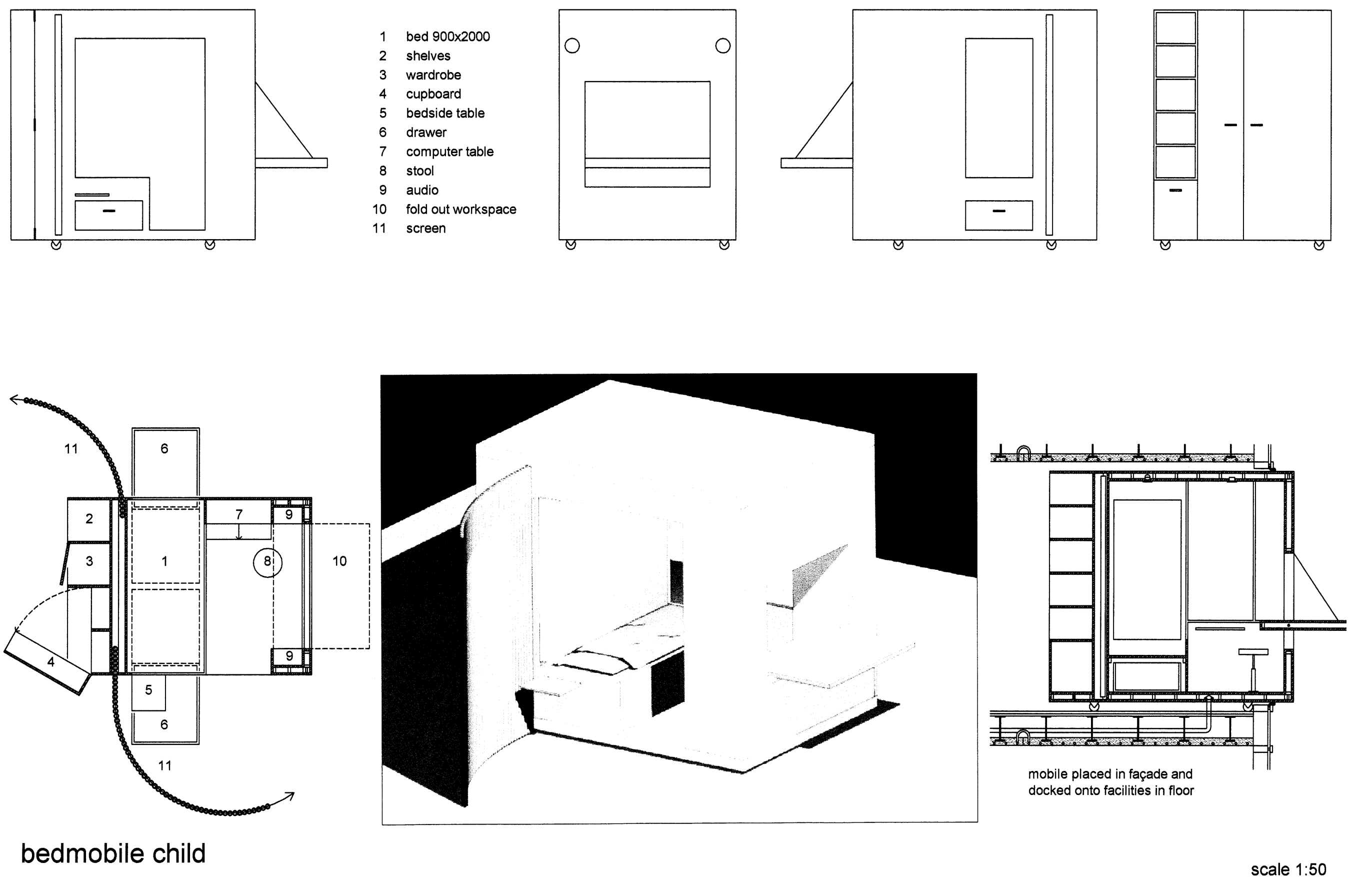

Fig. 11.13 Mobile Unity – Bedmobile for a child.

project is intended as a completely new approach to designing the contemporary commercial house. Originally created for the New Landhouse design competition organised by the Municipality of Almere in 2001, it is intended to challenge the conventional system of delivering houses in the commercial market. The concept is once again based on Böhtlingk's belief that architecture can begin with the design of furniture. He believes that this is particularly so for the vast majority of people who primarily understand the space in their homes, and the way they use it, in terms of where the furniture is placed. Böhtlingk takes what is clearly a limitation and unravels it to provide a positive design approach – using domestic furniture as the starting point for the design of a new dwelling. The project title 'Mobile Unity' derives from the fact that both people and their furniture are mobile, and when they interact they unite. It is influenced by Böhtlingk's 1999 design for a children's day-care centre in which he created a range of small, house-like, furniture objects that had real functions like sleeping and washing, but also helped with adjustment to a new environment through play. Instead of designing a specific house type for the competition Böhtlingk therefore chose to create a process which works by encouraging each member of the household to design their own furniture, and thereby leading them into the design of their own space. Further into the process the relationships of the different members of the family could also be understood in terms of the spaces they share together. This approach turns the design of a house on its head by creating the form and placing of the furniture first, and afterwards establishing the envelope into which it fits.

To convey this new process Böhtlingk has suggested a range of standard furniture mobiles which group together the various functions of a recognisable domestic space; for example, a bedroom, or a bathroom. These have been made into carefully designed units that are easily movable as an integrated element, a tactic that draws on the Markies experience. This introduction to design becomes comparable to a computer game, disposing elements and spaces to reach the goal of optimum choice and arrangement of facilities. Once the 'game' is complete the client could choose between varying degrees of standardisation and specification for both the furniture and the envelope to meet higher or lower cost levels for their dwelling. However, even if a client used a set of completely standard furniture mobiles their new home would still be unique and their understanding of the spaces they created more sophisticated than if they had simply filled a standard house layout with possessions purchased with regard to the usual considerations of fashion, cost and availability.

The mobile aspect of this project lies in two areas: the flexibility possibilities of rearranging the house by simply relocating the furniture mobiles within the envelope, and the possibility of reinventing the house when the furniture is redeployed to a new location. The challenge of this project is to first establish if there is sufficient interest in the market to allow a prototype to be created. The success of customised kit homes in parts of Europe, North America and Japan suggest this might be so. However, it would undoubtedly take a revolution in commercial practice to change most house builders' current practice away from providing fixed plans to which occupants must adapt, towards infinite variety in plans to which the builder must adapt.

Böhtlingk's design work is based in the realm of dedicated problem solving. His exploration of mobile concepts is pursued in this spirit – to provide another way in which to find appropriate solutions to specific design problems. The Markies is clearly a small project yet its media impact has been considerable. It has captured the general public's attention for its realistic yet romantic proposal for a mobile house. Design professionals recognise the simple yet sophisticated approach to detailed problems. It is undoubtedly in the tradition of the caravan and the mobile home; however, like the Airstream trailer it also has status as a design object. Unlike the Airstream, it manages to explode out of the linear space restraints determined by road transportation. It also delivers that quintessential element of the best mobile architecture – the sense of event when it transforms from its mobile to its static condition. In the case of the Markies this is also a metamorphosis from the enclosed and mundane to the open and extraordinary.

Further Reading

Capella, Juli, 'Microarchitettura II grande in serie' in *Domus* 797, 1997.

'Extendible Caravan with Tent Roofs' in *Detail No. 8, Mobile Structures*, December 1998, pp. 1422–1425.

Mollerup, Per, *Collapsibles: A Design Album of Space-Saving Objects,* Thames and Hudson, London, 2001.

PART 3
Specialists

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Carlos Moseley Music Pavilion

Date: **1991–1995**
Client: **New York Metropolitan Opera and Philharmonic and New York City Department of Cultural Affairs**
Architect: **FTL:** Nicholas Goldsmith, Ali Tayar, Amedeo Perlas, Ronn Basquette, Robert Dickey
Engineer: **Buro Happold and MG McLaren, P.C.**
Consultants: Lighting: **Peter Wexler,** Audio: **Jaffe Acoustics**
Contractor: **Quickway Metal Fabricators, Monticello, NY**
Cost: **$3.4 million**

Cadillac Mobile Theatre

Date: **1995**
Client: **Visual Services Inc., California, USA**
Architect/Engineers: **FTL, New York, USA:** Nicholas Goldsmith, Andrew Formicella, David Burke, Judy Choi, Izuhi Asakura, Paul Westbury, Eddie Pugh, Sui Ming Lui, Craig Schwitter
Contractor: Fabric: **Fabric Structures Incorporated**
Steelwork: **Quickway Metal Fabricators**
Cost: **$1.5 million**

Transportable Maintenance Enclosure (TME)

Date: **1993–1995**
Client: **US Army Natick Research Laboratories**
Architect/Engineers: **FTL, New York, USA:** Todd Dalland, Ian Liddell, Craig Schwitter, Sui Ming Lui, Angus Palmer, Paul Romain
Contractor: **Foster Miller Inc., Mass, USA; Vertigo Inc., California, USA**
Fiber Innovation, Mass., USA
Cost: **£660,000**

CASE STUDY 12

AT&T Global Olympic Village

Date: **1996**
Client: **Atlanta Committee for the Olympic Games**
Architect: **FTL, NY, USA: Project Principal Designer:** Todd Dalland; **Project Architect:** Andrew Formicella
Engineer: **FTL: Project Engineer,** Wayne Rendelly
Consultants: Lighting: **Animated Architecture,** Candace Brightman; Design: **Bruce Rodgers/ Tribe Inc.,** and Jeremy Railton and the **Entertainment Design Corporation;** Look of the Games: **MSTSD Architects,** Larry Sweat; Graphic Designer: Copeland Hirthler, Brad Copeland, Sarah Huei; Landscape Architects: **Roy Ashley and Associates**
Contractors: **Beers Construction, Atlanta**

FTL was founded in 1977 by Cornell University graduate Todd Dalland who was joined by Nicholas Goldsmith, also from Cornell in 1978. Whilst at college both architects had been interested in the design of buildings that involved lightweight unconventional architectural forms and on completion of their studies, rather than simply following the current stylistic trends, sought to explore architecture as a technologically driven discipline. Goldsmith went to work at Atelier Frei Otto in Stuttgart, Germany between 1975 and 1977 and learnt Otto's development process for tensile structures that utilised physical modelling as a design tool and form generator. Dalland's name for the firm was initially Future Tents Limited which clearly stated his initial ambition and expertise, however, both designers quickly realised that the potential for tensile structures went far beyond tents – such a name categorised their work unnecessarily and they therefore decided on the abbreviation FTL.

Physical modelling remains a very important part of their design process, however, as computer modelling techniques have become available the firm has adopted these for the dramatic improvements they offer in the design of complex structural forms. In the late 1970s and throughout the 1980s the architectural style of Post-Modernism, with its skin-deep clumsy references to the past characterised most of North America's commercial architecture. This was not the most receptive period for a small firm to promote a new form of building based on new materials and technologically advanced techniques, however, FTL developed a strong client base that helped expand their practical experience in their chosen design area. This has left them well placed as experts in the field of US-based lightweight architecture. Between 1991 and 2000, FTL collaborated with the English multi-disciplinary engineering practice, Euro Happold, to form FTL Happold. However, these firms are now once again completely independent, operating under the more descriptive name of FTL Design Engineering Studio.

FTL have now worked on more than 800 separate projects and have won more than thirty awards for building work that has varied dramatically in size and function. Not all their work is tension structure based, though even the prestigious interior design work for the big fashion houses of New York like Donna Karan and Calvin Klein began with the creation of temporary showrooms. This exhibition work led to Todd Dalland being asked to design the temporary tented theatres for New York's biannual fashion shows situated in Bryant Park, Manhattan. As FTL Happold, the practice has designed and built many dramatic, permanent buildings. The Pier Six Concert Pavilion is located on Baltimore's Waterfront, and comprises a 3500-seat concert pavilion with masonry stage facilities and a 2800 square metre tensile fabric roof structure. The Boston Harbour Lights Pavilion is a seasonal amphitheatre on Boston's Fan Pier. This building has seating for 4500 people and its tensile roof covers an area of 3700 square metres.

The lightweight nature of tensile structures means that they are particularly suitable for use in portable buildings and this has led to this type of building becoming an important part of FTL's workload. The practice has created designs for standard commercial marquee tents such as the 'New Century' made by Anchor Industries Incorporated and the 'Genesis' made by Eureka Party Tents. Though these designs are commercially based and conform to standard layout patterns, their roof profiles exhibit a far more dynamic form than is normally associated with commercial marquees. Their curved organic shape is highly tensioned which not only forms a smoother profile but is also stronger and more resistant to wind load. The tents use vinyl-laminated polyester fabric in modular patterns that incorporate repetitive erection and fixing components. A roof pattern may be repeated to form an unlimited size floor plan though divided by vertical columns. Walls are separate from the roof structure and a number of different specifications are available including opaque, clear, mesh and window pattern. Tent poles are obtainable in different materials and sizes that accommodate a variety of ground conditions and also allow a tent to be erected on an uneven surface. An adjustable centre pole with a hand-operated jack allows centre sections to be elevated with ease to create dramatic internal spaces not possible with conventional commercial marquees.

Carlos Moseley Music Pavilion

It is the specialised dedicated designs that are of greatest interest in FTL's work as they indicate the dramatic opportunities that tensile structures have in the field of portable architecture. Carlos Moseley was the chairman of the New York Philharmonic who in 1965 set up the first free concerts in the city's parks. In 1991, sound and lighting designer Peter Wexler proposed that the New York Philharmonic and the Metropolitan Opera could take to the parks with a more sophisticated stage than ever before, bringing quality of sound and performance together in the setting of an outdoor show that used the city's skyscrapers for a dramatic backdrop. The concept was to create a portable venue that would support thirty outdoor shows throughout the various city parks each summer. The proposal was that the pavilion should be capable of erection with minimal effort, without harming the natural environment of the locations, and without special facilities beyond that provided by the pavilion itself. The facility would have to be moved to the site on standard 3.9 metre high by 13.5 metre long articulated lorry trailers (Fig. 12.1). Nick Goldsmith realised that rather than providing a complex kit of parts to make up a structure, the trailer beds themselves could become part of the system and by adapting available crane technology, the main structure could be erected almost automatically. This would save time and operation costs as a large trained assembly crew would not be required.

The Met/Phil pavilion consists of four main elements – a tripod like truss system, a tensile canopy, a folding stage, and a series of collapsible amplification towers. The trailers are manoeuvred into position on site to form the support for the corners and back of stage area. Hydraulic foot pads swing down from the trailers to support the stage firmly and are then adjusted to create a level platform (Fig 12.2). Hydraulic pistons push out the stage which is made of marine ply panels folded up like an accordion for transportation and supported in position by six lightweight aluminium beams. When erected the stage area is big enough to take a full orchestra.

The three trusses are hinged in the centre for transportation and when they arrive on site they are folded out to their full length of 26 metres (Fig. 12.3). In order to be capable of accurate three-dimensional positioning the base of each truss has been designed to pivot vertically and rotate around

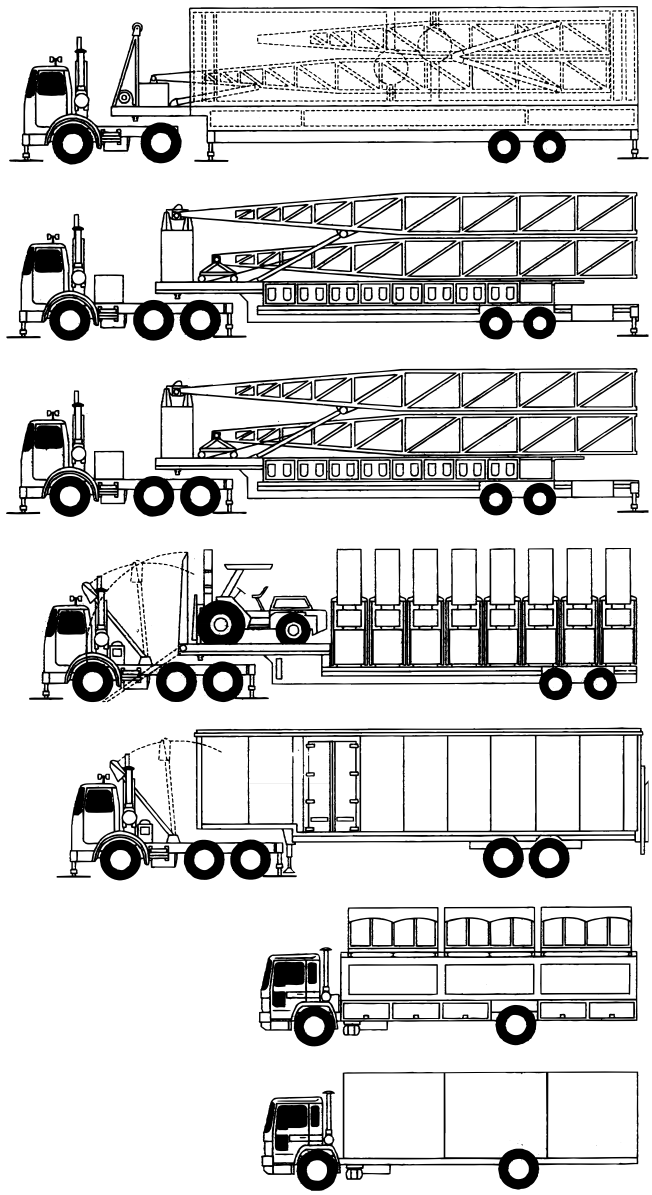

Fig. 12.1 Carlos Moseley Music Pavilion, FTL Happold, 1991. The performance facility for the New York Metropolitan Opera and Philharmonic Orchestra is transported on seven lorries, five of which form an integral part of the structure.

a pin. The two trusses on either side of the stage are extended first, locked into their full length and their apex ends are then brought together. The third truss is then attached at the apex but still in its folded form. This truss has a special hydraulic

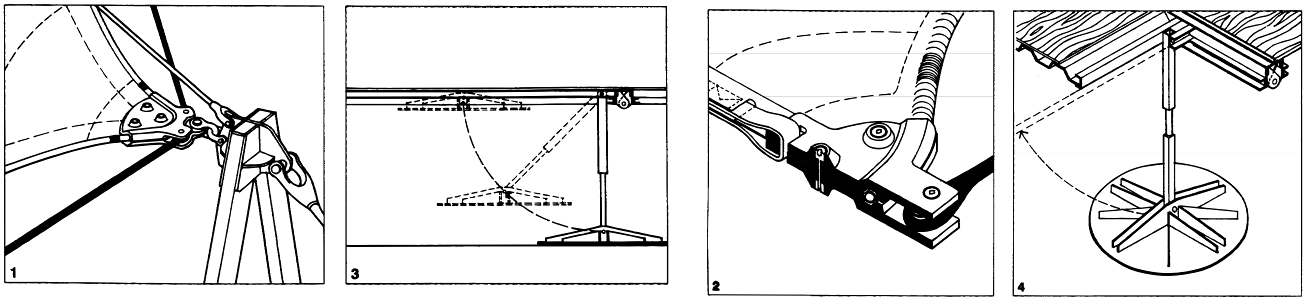

Fig. 12.2 Carlos Moseley Music Pavilion, construction details. (1) and (2) Aluminium connector plates are used at the edge of the membrane to gather webbing and rope connections. (3) and (4) Steel foot pads which are adjustable in height are transported flush against the trailer and swung down into position to support the stage.

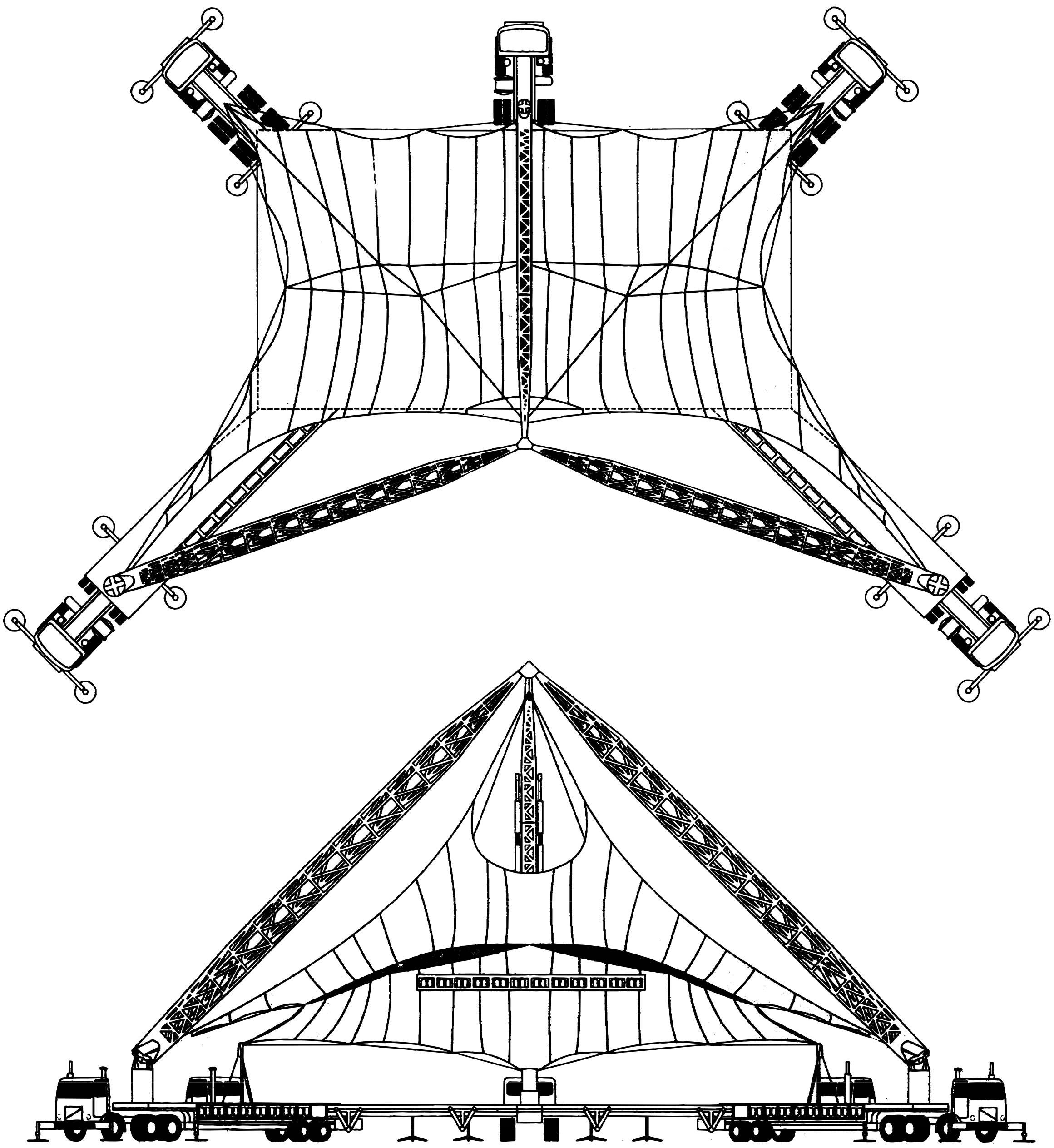

Fig. 12.3 Carlos Moseley Music Pavilion, plan and audience elevation.

ram that then straightens the truss out and pushes the apex of the assembly to its final position nearly 21 metres above the ground. The vertical and outward thrust from the assembled structure is accommodated by the trailer beds which are weighted with additional concrete ballast instead of conventional foundations. Once in position, the whole structure is locked into place by steel pins before the hydraulic systems are turned off (Fig. 12.4).

The tension structure membrane is a PVC-coated polyester fabric which is rolled into a protec-

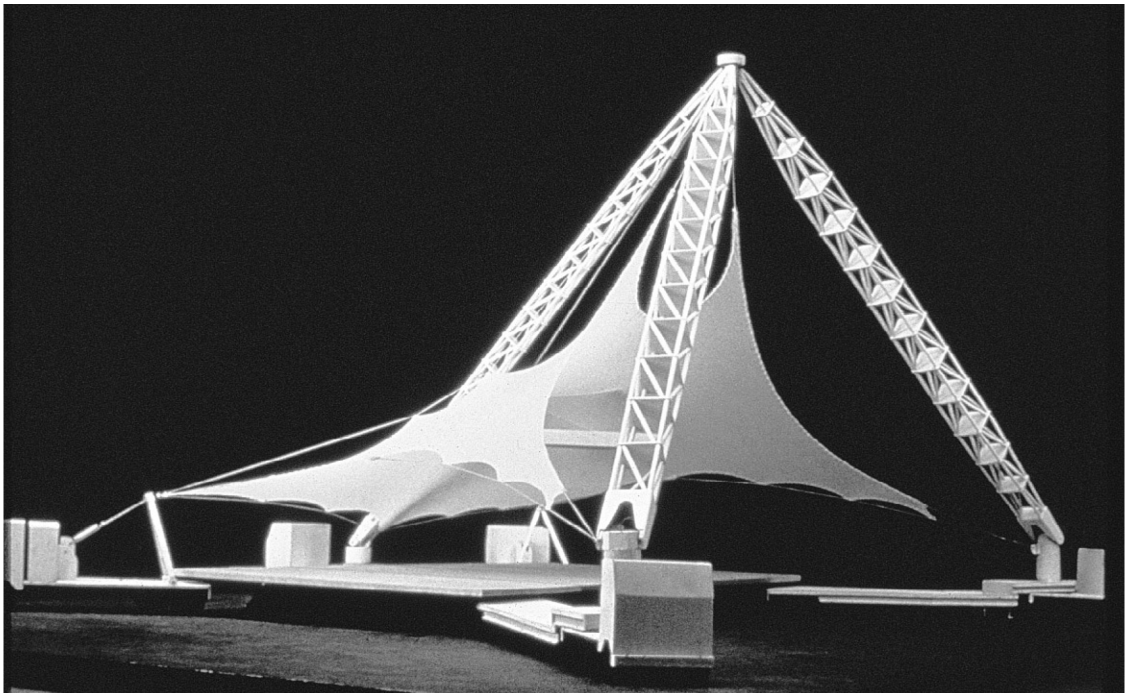

Fig. 12.4 Carlos Moseley Music Pavilion, development model.

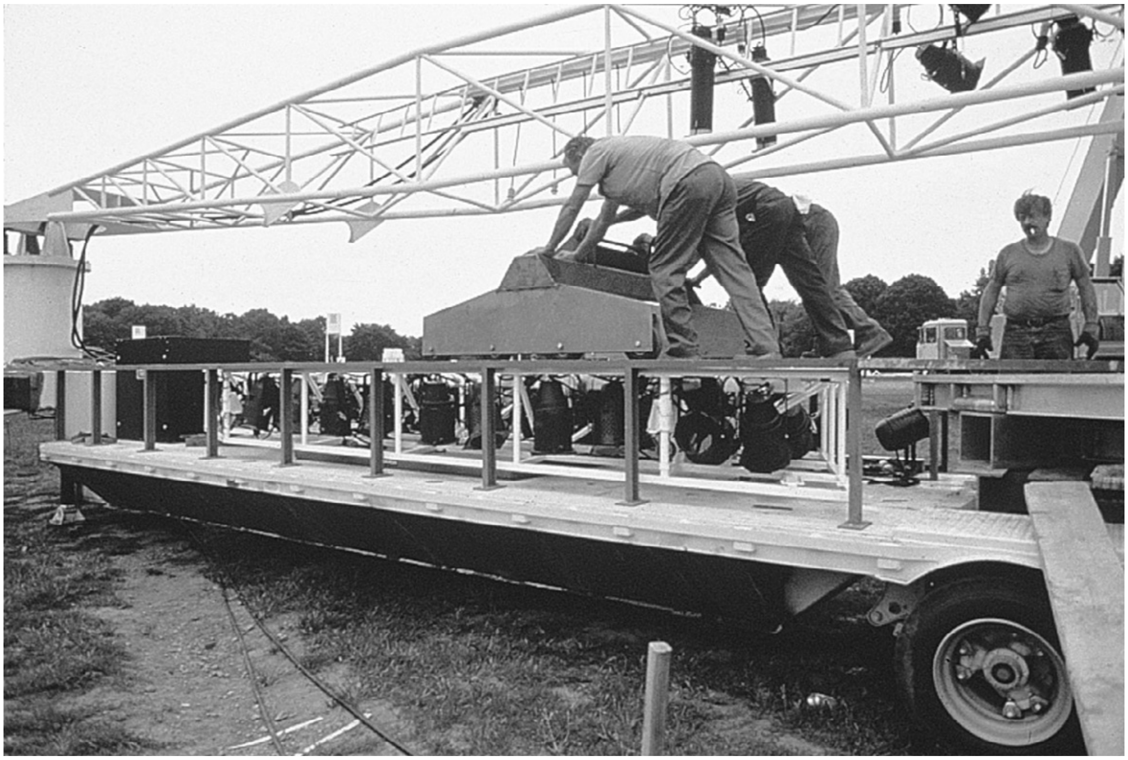

Fig. 12.5 Trusses are transported with lighting equipment wired in place. The facility can be erected in four hours.

Fig. 12.6 The stage is supported on trailers which are stabilised by foot pads. The vertical white pillars provide a backdrop to the stage and help project sound out to the audience. One of the vertical speaker units.

tive sleeve for transportation. For erection it is connected to the lower parts of the truss by polyester ropes and then raised by winch into position. The use of ropes rather than cables means that these fixings can remain connected to the fabric membrane when in transportation and storage. This saves valuable time during the deployment procedure, though it does mean that these less durable items have to be replaced after two seasons. The canopy serves several purposes. Its taut surface (which does not flap in the wind) protects the orchestra from the rain and reflects sound towards the audience. It also serves as a dynamic backdrop to the stage and a surface for lighting effects. An additional inflatable projection screen for higher quality images may also be raised above the performance area. The truss frames incorporate lighting which is permanently wired into the structure. There is also an additional dedicated lighting rig suspended across the top of the stage below the tension membrane (Fig. 12.7).

Outdoor performances have their own special acoustical problems which are particularly problematic for classical music, which does not normally rely heavily on artificial amplification. To try to replicate something of the concert hall quality in an outside space a special transportable speaker system has been developed by Jaffe Acoustics. These speaker modules are placed in

Fig. 12.7 Carlos Moseley Music Pavilion, FTL Happold, the entire facility against the backdrop of the Manhattan skyline.

amongst the crowd in positions that extend out from the stage area. Once in position, stabilising legs are extended and then pinned down. The speakers are then elevated into a position five metres from the ground. Microphones on stage transmit the sound of the performance to a remote booth where it is mixed and broadcast by radio to the independent, battery-powered speakers. The technicians calculate a tiny delay in broadcasting time to mimic the time the sound would take to travel from the stage to the listener and also alter the volume so that the sound nearest the stage is loudest. In this way they are able to programme in the precise acoustical differences and echoes which are obtained in a concert hall but absent in a large open space (Fig. 12.6).

The entire facility can be erected in just four hours, repacked in even less time, and reerected the next day, enabling concerts to take place at different locations on consecutive days. It can be transported in seven vehicles, five of which have been specially converted. Each of the three trusses is transported on a dedicated trailer which is towed by a conventional rented articulated truck. Another trailer carries the speaker towers and a fork-lift truck used to deploy them around the site. One other smaller vehicle carries the self-erecting stage surface and two others carry the tensile membrane and lighting and sound equipment. When the design of this facility was placed before the New York city authorities for authorisation it created some problems regarding who would provide the licences – was this a building or a vehicle? Eventually the Department of Cranes and Derricks was sought to give final approval.

The Met/Phil pavilion is a unique example of portable building that contributes to the sense of performance by the creation of a dramatic event. The structure has a charismatic form that conveys the kinetic quality inherent in its erection process. After eight years in operation the structure has proved flexible in use, though specific alterations and additions have been added for special events like the 'Pavarotti in the Park' concert in 1993. A new membrane has now being made of a PVC polyester base coated with PVDF, a new Teflon-type coating that implements the advances in technology since the first membrane was made.

It could be stated that the Met/Phil pavilion is not really a building as it does not contain space or create a specific division between the external and internal environment; however, it must be argued that it is definitely architecture, as its presence is distinctly building-like and recreates the visual and aural qualities of a most complex building type, the auditorium (see Fig. 12.7). This project utilises technology, not in a conscious search for a dramatic visual tour de force but as an essential tool in the functional elements that define the pavilion's purpose. The elements which are made to operate in a kinetic and movable way do so because they are essential for the smooth deployment and operation of the facility. In this project, hydraulics and lightweight structural systems commonly used in other situations, are required to perform new tasks. Their successful use indicates further possibilities for technology transfer from this and other familiar, widely available and well-tested equipment. The Carlos Moseley Music Pavilion is an important example of portable building as its quality of operational performance and construction detailing provides encouragement to designers who wish to explore further the latent opportunities of the building type.

Cadillac Mobile Theatre

In January 1995, the California-based exhibition organisation company, Visual Services Incorporated, approached FTL with a brief to create a completely mobile enclosed theatre space. The company had been commissioned to organise and present a touring facility that would publicise Cadillac cars and they required two separate facilities that would tour in parallel down the east and west coasts of the USA in August that year. Once the tour was complete, the theatres would then be made available for a wide range of other performance and publicity events, therefore the design must not only be robust and easy to deploy, but also adaptable to as yet unknown uses for several years into the future. The exact sites that the theatre would use were not known; however, typical situations ranged from city centre parks to tarmac parking lots and public squares. FTL were appointed because of their previous experience with portable structures (in particular the Met/Phil pavilion), though in several important ways the project was quite different. Most significant was

Fig. 12.8 Cadillac Theatre, FTL Happold, 1995. This sequence of photographs show the first trial erection in the summer of 1995. The apex joint is supported by the crane whilst one leg is pushed into place by a fork-lift truck.

Fig. 12.9 Once in position the base of the leg is fixed onto its foundation which is located by helical ground anchors.

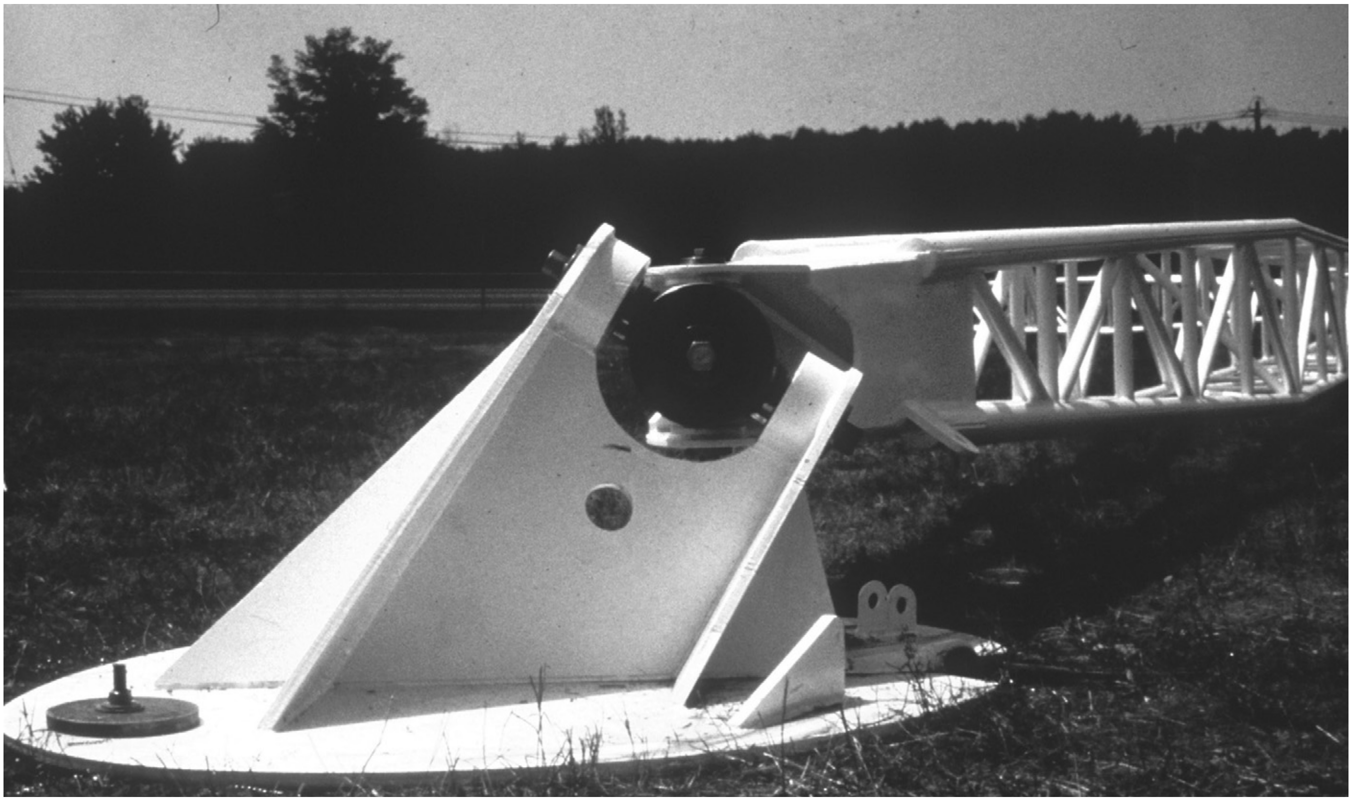

Fig. 12.10 This complex rotating joint is necessary to accommodate movement in the two fixed bases as the structure is erected.

that the client required a genuine building rather than an open pavilion. The theatre would have to enclose space completely, protect the occupants from rain and wind and excess heat and also have a black-out facility to allow complete control of the internal visual environment during the day and night. If the tour budget was to be met, the building would also need to be transported in a much more modest manner than the seven vehicles used to transport the Met/Phil structure. The Cadillac building was also required to be much more flexible in its final form, capable of use for a wide range of events from pop concerts to trade shows.

The clients were very experienced at mounting travelling shows, having started in the business as road managers for pop and rock musicians, graduated to tour managers and then the operation of any kind of temporary event. However, apart from the criteria that the building should fulfil their functional requirements efficiently, be within budget, and have a strong visual image they gave no guidance on form or design strategy. The tripod structural arrangement that had been used for the Met/Phil canopy had proven its practicality over several years' operation and was consequently used as a starting point in the new design, though differences in budget and operational circumstances meant that the concept had to be modified significantly. The Cadillac Theatre therefore also consists of a tripod from which is suspended a membrane structure, however, the deployment procedure uses less automatic systems than the Met/Phil and makes more use of standard rental machinery. This equipment is familiar to the client and as it can be hired by the day during erection and dismantling, from a location close to the deployment site, saves on capital costs during manufacture and transportation costs during use.

The theatre requires just two trucks for transportation, one to carry the roof structure – triangular roof beams which fold in half for transportation – and one to carry the membrane roof and walls, foundation plates and air conditioning plant. Deployment requires a crane and a fork-lift truck (with wide tyres if used on unmade ground). First the three foundation pads are laid on the ground and fixed with proprietary 'Platypus' ground anchors thrust into place with a jack

Fig. 12.11
The membrane is hoisted into position. The perimeter masts are positioned whilst the membrane is partially erected.

hammer. After the anchors are set they are proof-loaded to ensure they can take the axial thrust from the full structure. Then the trusses are unfolded and fixed at the centre. Two of the trusses are connected to their foundation pads and together at the apex joint. The third is connected to the other two at the apex joint and its base is placed in a special pocket temporarily fixed in the fork-lift truck. The crane hoist is connected to the apex joint and as it lifts this up the truck moves the base inwards to a position over the foundation where it is dropped into place and fixed (Figs 12.8, 12.9). A complex movable universal joint is required at the bases of the two fixed trusses to transfer the forces to the foundation and avoid axial stress during erection (Fig. 12.10).

The 1000 square metre membrane is assembled from only three fabric panels which when stressed form a complex saddle shape called a 'hypar'. The use of just three main panels reduces site assembly time and the risk of rainwater leaks at the joints. These are formed using a double lace line that uses polyester rope with twin rain flaps to protect the joint from water ingress. The membrane is hoisted from the centre by a cable that passes inside one of the trusses (Fig. 12.11). When the membrane is

Fig. 12.12
The fully erect building.

Fig. 12.13 The full travelling facility including hospitality tent and air-conditioning units.

three-quarters of the way up and still relatively loose the aluminium perimeter poles are set in place. This makes tensioning the kevlar edge ropes easier once the membrane is fully erected. Once in position, a hydraulically operated steel pin is located into a catch plate at the apex which locks the membrane structure in place, thereby taking the load off the hoisting cable. The walls are made from the same polyester PVC fabric which is white on the outside and black inside to form a complete internal black-out. These panels may also be used as awnings or entrances at any point by the use of additional props. The total erection process takes eight to ten hours depending on ground and environmental conditions (Fig. 12.12). Though the two theatres will initially operate independently they can also be erected together and used as a single space with the addition of a connection membrane (Fig. 12.13). The building was used in this form at the Atlanta Olympics in 1996 (see Case Study 8d).

This project was taken from design development to first operation in just thirteen weeks. This compressed contract period caused some problems as preferred experienced builders in the field were busy and unable to programme-in the extra work. For this reason two separate contractors were used. It was essential that a specialist membrane manufacturer make the fabric (in this case Fabric Structures Incorporated). However, a conventional steelwork manufacturer could be employed to fabricate the compression structure as this work could be strictly controlled through precise workshop drawings and specifications. Because of the escalated programme, the specialists and the client were involved in the design process right from the conceptual stage, commenting on design decisions as they were made so that unexpected conflicts would not delay the programme. Paul Westbury, who supervised the Buro Happold side of the design process, comments that it is generally better if a single contractor controls the entire project as it is at the interfaces of expertise that problems occur; in material terms this might be fabric to steel junctions. Though the design did not need to change dramatically as the project was built, detail changes were incorporated and even as the trial erections took place the deployment sequence altered, based on the riggers' experience and knowledge of day-to-day running operations. The design life of the steelwork is fifteen years, and the membrane approximately five years depending on the care taken in handling.

The Cadillac Theatre exceeded the client's expectations in terms of its appearance, which despite the large-scale models used in the design stage failed to convey the quality of the form and space that the full size building possessed. The level of attention to erection details also pleased the clients who were used to dealing with less finely tuned standard products.

Westbury believes that there is potential to improve the design of buildings like the Cadillac, particularly in the use of automatic erection procedures such as hydraulically operating trusses. In fact the initial concept for the building was to convert a crane; however, crane structures are designed for very different dynamic stresses than a building truss, even a movable one, and time did not allow this avenue to be explored. The potential for movable buildings of this type and function is only just beginning to be realised. The concept of bringing information and entertainment directly to the public, created almost instantly in familiar, well-frequented locations, is a powerful marketing tool not yet fully understood by British companies. US businesses are several years ahead in the development of this field. Though a building like the Cadillac Theatre may be more expensive than a conventional one (the two units together with full fit-out and additional standard commercial marquees used for restaurant and kitchen facilities had a combined cost of $1.5 million), such buildings are capable of reaching a much greater population over a given time period.

Though the image of the building was important to the designers they state categorically that its form was generated by functional and constructional issues. They had no ambition to generate a building that looked specifically portable, but rather that it conveyed in its imagery the nature of its structural system and the dynamic qualities of the materials utilised to achieve its purpose. Though the building has been designed to be movable this is simply another part of the design criteria that has led to its ultimate form, and this design constraint should therefore be understood as just one component, though an important one, in a complex architectural brief and not something that has dictated the entire concept.

Transportable Maintenance Enclosure (TME)

The Transportable Maintenance Enclosure project resulted from a search by the US Army to find a quickly deployable large area maintenance shelter, primarily for helicopters. Air-supported structures can be very light to transport and fast to erect; however, the most common pattern is the low-pressure air-filled space which is entered through an air lock. The internal pressure of such buildings is not high (typically 0.1 psi or 0.007 kgs/sq.cm.) which means that people can occupy them without discomfort; however, large openings such as those that would be required for the entry of vehicles, especially large ones like helicopters, are not possible as the building would collapse when they are opened. Another problem is that the pressure needs to be constantly maintained by pumps that top up air lost through leaks and openings. One solution to these problems is the air beam structure. Air beams have been used in the past; however, limitations in material quality has meant that there has been a constant risk of cataclysmic failure as the air is of such high pressure that if a rupture occurs in the skin its rigidity is lost immediately.

FTL had been involved in other experimental projects for the US Army Natick research laboratories and in 1993 were commissioned to investigate the possibility of making a relocatable hangar that would be air-transportable, weigh less than 900 kilograms, contain a space 9 metres by 30 metres by 6.7 metres high and be capable of installation in less than six hours in any sort of environmental conditions from the desert to the arctic. At that time, suitable commercial products did not exist. However, even though some that would fulfil the initial brief have now become available, the client has persisted with prototype development as they have realised the greater potential of their dedicated system. In a project of this type, weight and instal-

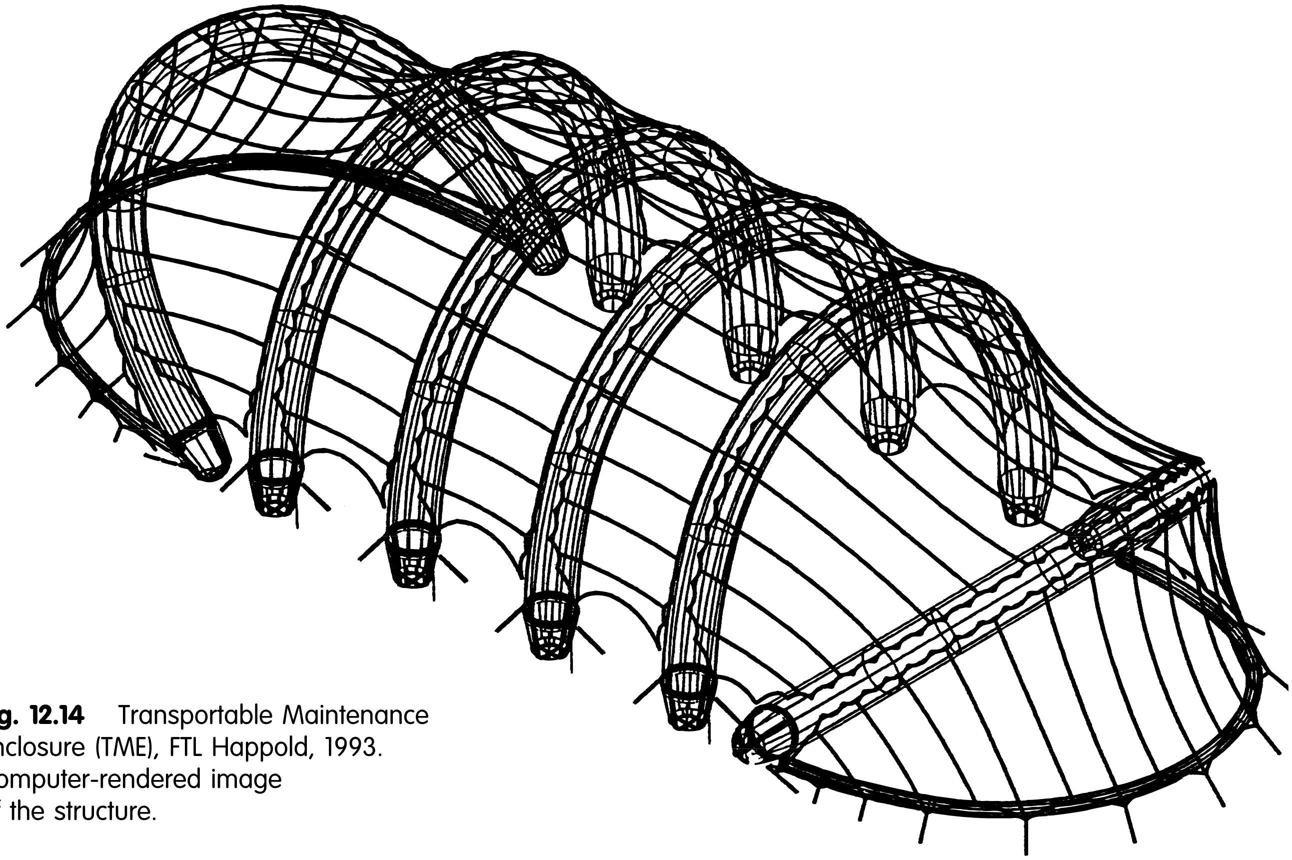

Fig. 12.14 Transportable Maintenance Enclosure (TME), FTL Happold, 1993. Computer-rendered image of the structure.

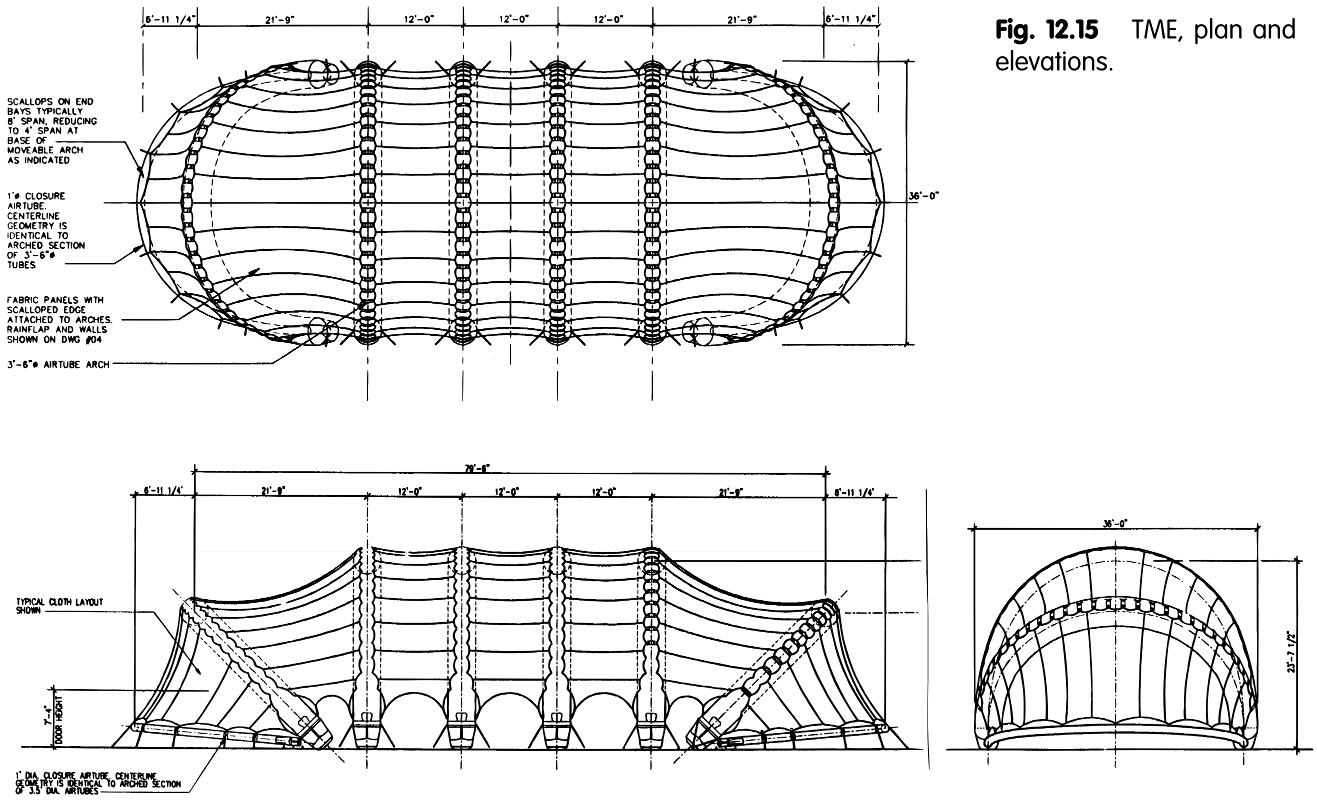

Fig. 12.15 TME, plan and elevations.

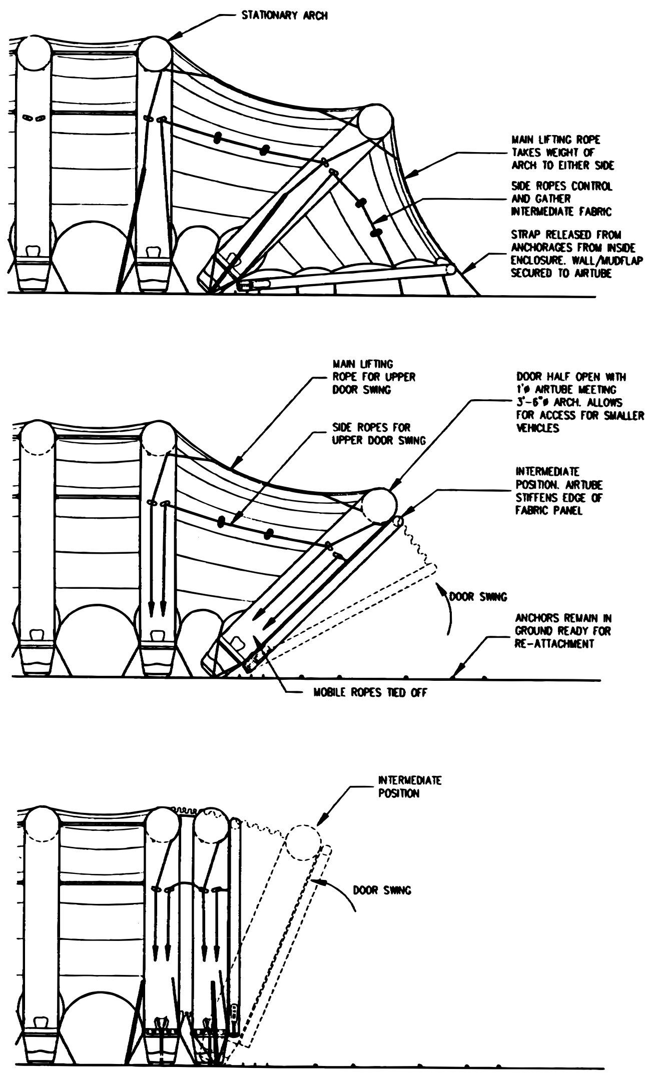

Fig. 12.16 The opening procedure which allows full access to the entire volume. There are also small personnel doors in the sides.

lation time are more important factors in the design process than budget and image. The main design parameters were all based on constructional and logistical issues, though the designers also believe that the resultant form expresses its transportable nature in every way as an entirely 'soft' organic structure.

The TME utilises PVC-coated polyester membranes to form structural arches, four vertical ones in the centre and two which are inclined at the ends (Figs 12.14, 12.15). These tube-like structures are 1075 mm in diameter and span 9 metres with a height of 6 metres. The air pressure within the tubes is 0.35 kgs/sq.cm. or 5 psi, about a seventh of the pressure inside an ordinary car tyre. Though they must be very airtight and resistant to puncture the relative area in which leaks may occur is reduced as the intermediate membranes between the arches need not be airtight (Figs 12.17, 12.18).

Fig. 12.17 The arches are held down to the ground with webbing belts strapped to ground anchors. The membrane has a continuous polyester rope around its edge which passes through connectors to triangular metal eyes fixed to saddle-shaped spreaders on the arches.

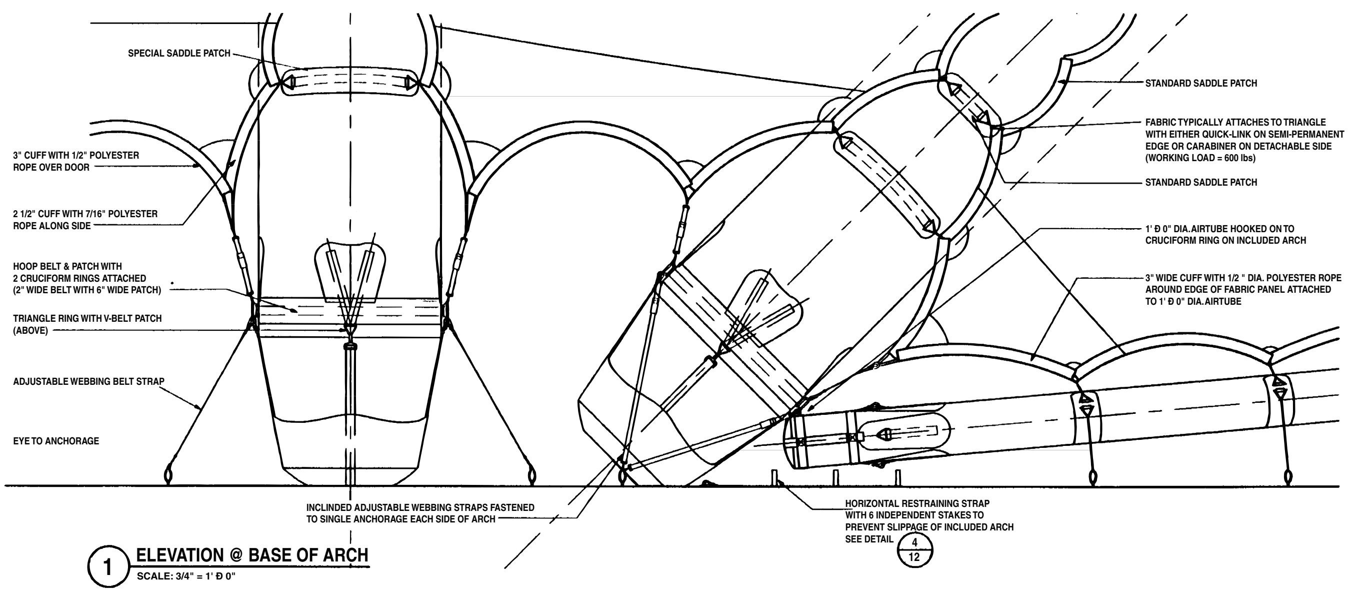

Fig. 12.18 LanMAS exterior.

The 24.5 metre long building has personnel doors in the side membrane and a vehicle entry at each end which can be opened across the building's entire width. This consists of a 300 mm semi-circular air-filled tube situated at ground level to which is attached the end wall fabric. To open the door the tube is raised until it is flush with the main inclined arch (Fig. 12.16). The building takes less than one and a half hours to deploy but once in position can be inflated in just twenty minutes. First the fabric is unfolded and the skins and tube arches are attached in their deflated state. Next the air tubes are inflated and finally pressurised and sealed off. Once erected, the inflation air pumps can be removed and used elsewhere. The total weight of the structure is 1150 kilograms which is more than the target specification stated, however, the building exceeds the design brief in all other areas, most dramatically in its deployment time which is 25 per cent of that originally envisaged. The main contractor's team carried out the first few trial erections after which it was deployed more than thirty times by non-specialised soldiers.

Foster Miller Incorporated, a Boston-based military contractor, was the general contractor for the project and provided the main liaison between designers, subcontractors and client. No conventional building contractors were used and it was difficult to find manufacturing experience that could effectively produce components of the appropriate quality. One particular problem was the high-pressure tubes which were subcontracted to an inflatable raft manufacturer who had to adopt new technology to make the air beams (Fig. 12.20). Problems with the beam construction quality was the main reason for delays in manufacture that led to the initial prototype being delivered behind schedule.

The designers had a much closer involvement with the construction process than in a normal building, providing detailed information on cutting patterns and fabrication (Fig. 12.21). Despite this, the general construction strategy was easier as fewer trades were involved. Before the main building was assembled a complete tubular arch was made in prototype form and tested for performance against the computer-based analysis. Only minor amendments were made to the design during the construction process.

Though the TME had many successful aspects about its design, it has led to the development of a more advanced prototype that has substantially increased performance characteristics. The Light Area Night Maintenance Shelter (LanMAS) uses the same principles as the TME but makes use of more advanced tubular arch technology (Fig. 12.19). This new design uses smaller 300 mm diameter tubular arches at a higher pressure of 4.23 kgs/sq.cm. or 60 psi. The higher performance requirements for this structure are met with the use of new materials such as braided kevlar which has much higher

Fig. 12.19 LanMAS interior.

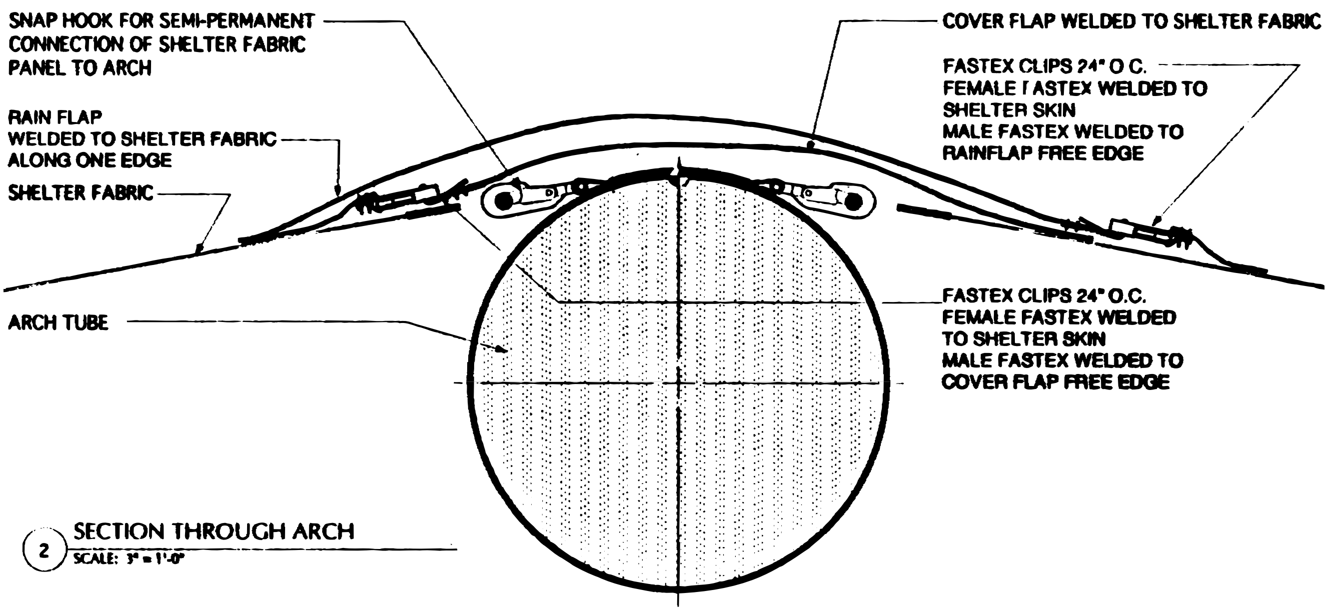

Fig. 12.20 Section through air-beam arch. All covering membranes are overlapped for environmental control and black-out reasons.

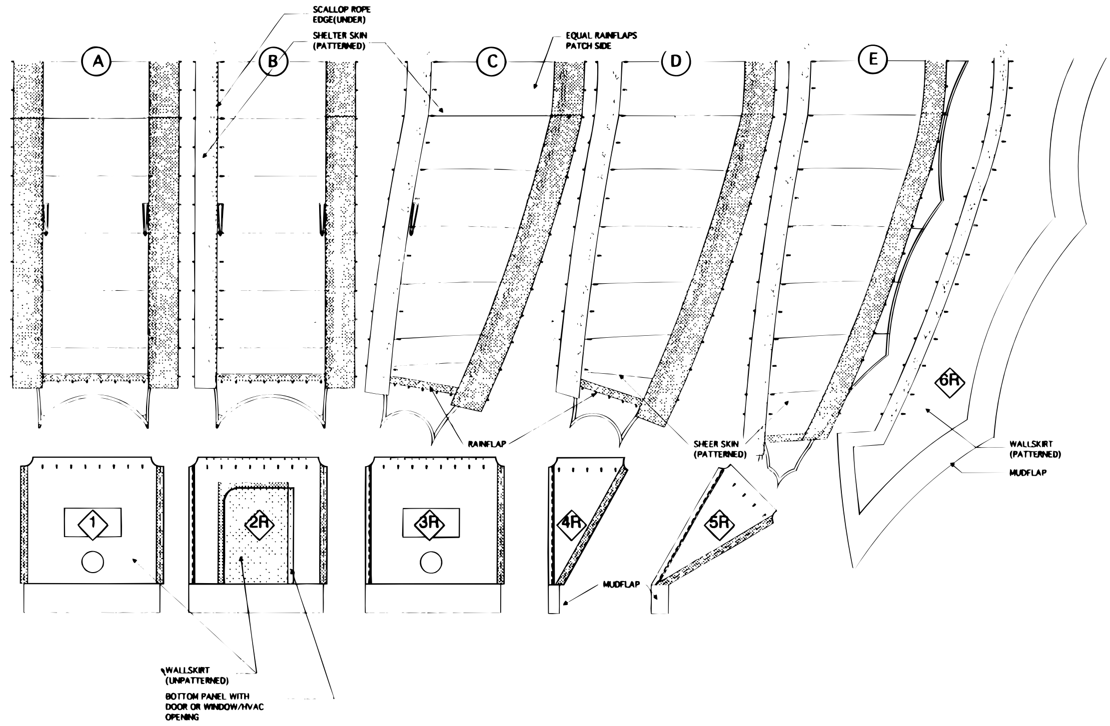

Fig. 12.21
Panel assembly details.

strength fibres than polyester for less weight. The new arches consequently weigh only 34 kilograms each compared to the 113 kilograms of the TME. A ful-scale prototype arch has been successfully built and was able to support a point load of 317 kilograms with only 100 mm of deflection (Figs. 12.22 and 12.26). A full-scale prototype building is now under construction.

FTL's latest work in air-beam supported architecture is in collaboration with the California Company Vertigo Inc. on a US federal government funded project to make a more ambitious mobile military shelter. The Aviation Inflatable Maintenance shelter (AIM) (Fig. 12.23) is designed to enclose any helicopter currently operated by the US Army, including the heavy lift CH-47D Chinook. This building must therefore have a clear span of 20 metres at a height of 5.5 metres and a length of 40 metres. To achieve this size the air-beams must span more than 22 metres and be at least 30 metres long. The building is to be erected in less than 24 hours by ten men, transported in two standard ISO shipping containers and have a minimum useful life of eight years.

Vertigo make air-beam supported camouflage netting, self-inflating paragliders for bringing large objects safely to earth, and the Bare Base Shelter which is a prototype 10 × 6 metre air-beam supported vehicle maintenance building that weighs just 390 pounds (177kg) and takes less than two man-hours to erect (Fig. 12.24). Working with Fiber Innovations Inc. of Walpole, Massachusetts, the company have created a custom braiding machine that can manufacture continuous 0.75 metre diameter tubes up to 35 metres long, capable of operating at a pressure of up to 100 psi, with an air leakage rate of less than 10 per cent per week (Fig. 12.25). Most significantly, the use of this machine also reduces the cost of manufacture by 50 per cent compared with previous methods.

Dalland believes that as air-beam technology prices drop and reliability rises it will become attractive to other organisations besides the military and the government.

Such buildings obviously have potential for use outside the sphere of military operations, being extremely lightweight and compact to transport and once on site are available for use almost instantly. The structure is surprisingly resistant to damage and the arches can even be deflated one at a time for repair or replacement without the building collapsing. The development of air-supported buildings follows the pattern of much spin-off technology which has been prepared for use in one dedicated function and subsequently been exploited elsewhere. Extreme operational and functional requirements lead to innovative forms of building which would not usually be found in more

Fig. 12.22 LanMAS, small section arch prototype testing

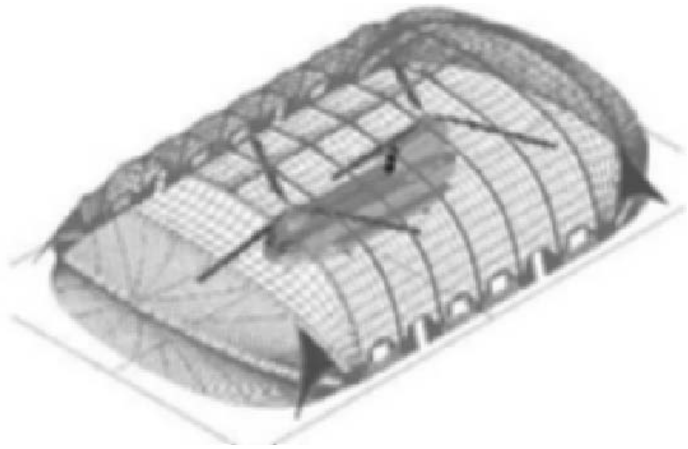

Fig. 12.23 Computer drawing of the Aviation Inflatable Maintenance Shelter (AIMS)

Fig. 12.24 The Small Air Force Shelter (SAFS), an air-beam supported portable shelter built by Vertigo Inc.

Fig. 12.25 The new generation of slender air-beam tubes.

Fig. 12.26
LanMAS, test inflation of a prototype bay.

normal circumstances, however, their wider potential becomes obvious once an operational prototype is available. The perceived risk of employing new technology then becomes mitigated by the benefits it clearly offers and it is transferred more readily into general use. This phenomenon is true for building technology in all areas of construction; however, because of its more demanding operational criteria, it is particularly so for portable building design.

AT&T Global Olympic Village

The provision of temporary facilities for large sporting events is common; however, the higher expectations and more complex strategic ambitions of a meeting such as the Olympic Games mean the infrastructural arrangements can approach the level of complexity of permanent urban layouts. City-sized roads, pedestrian routes, and servicing arrangements are required to cater for large numbers of temporary buildings that fulfil all the functions found in a permanent urban neighbourhood. However, the infrastructure needs to be established in a remarkably short period and, if the project is to be both economically viable and ecologically aware, should not waste resources on the construction of permanent buildings that will become redundant once the event is over.

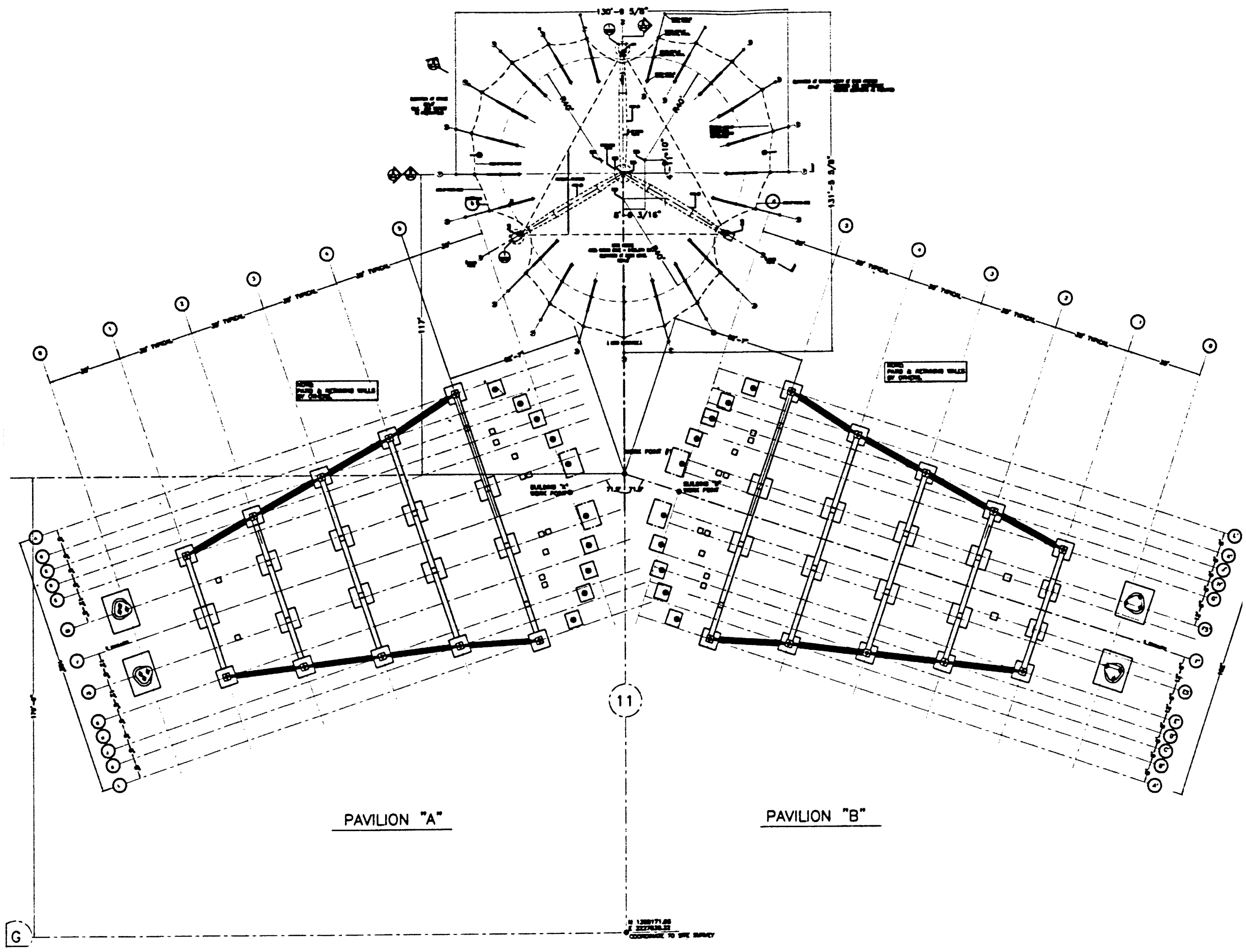

Fig. 12.27 Plan showing the twin portal frame pavilions and the former Cadillac Mobile Theatre. The temporary stage area was situated in the centre of the portable elements.

The athletic venues and related facilities for the 1996 Olympic Games in Atlanta, USA, were resourced in three ways – approximately one-third were existing local sports facilities, one-third were new permanent construction, and one-third (about 150,000 square metres) utilised temporary and relocatable buildings and interior adaptations. FTL were one of the key design firms involved in planning the infrastructure of the Atlanta Games, advising in several different roles during the design and implementation process. Their work ranged from comprehensive organisational tasks, such as

Fig. 12.28
AT&T membrane being deployed.

Fig. 12.29
AT&T during erection – the longitudinal cables have yet to be fully tensioned.

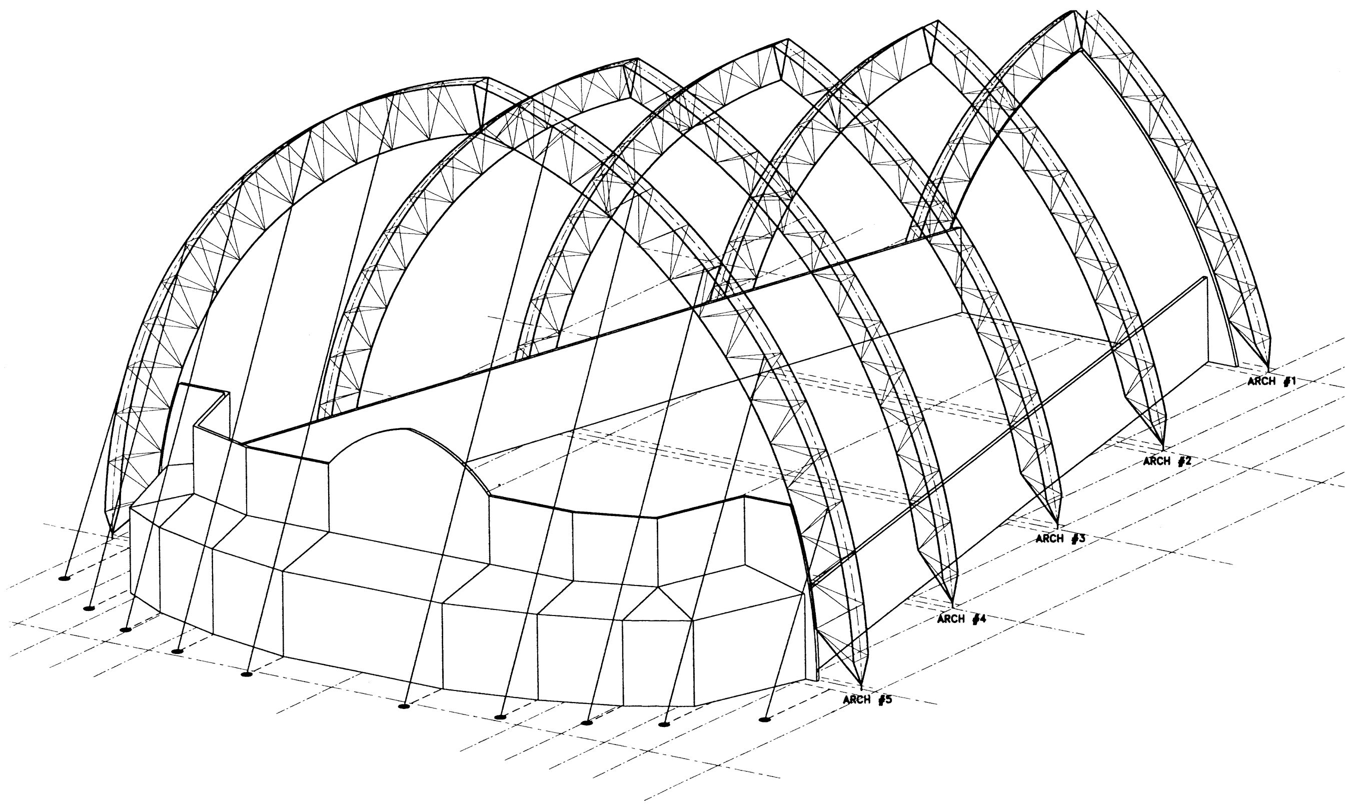

Fig. 12.30 Perspective showing location of perimeter glazed wall.

planning a range of temporary hospitality villages around the city, to specific construction projects, such as engineering the 40-metre tall 'pyramid' structures at the Athlete's Village. Todd Dalland's experience of organising large multi-facility events such as the Seventh on 6th Fashion Show held each year in New York City's Bryant Park, proved invaluable in determining the requirements of the Olympic Games' temporary infrastructure and urban planning. The practice were co-designers of the portable kit of parts that established the 'Look of the Games' which was used in many of the forty separate venues as a unifying feature and to help direct and orientate the hundreds of thousands of athletes and visitors. These urban-scale temporary structures were made from standard rental items such as scaffolding, with additional specially designed modular elements such as printed fabric panels, tensile membranes, and above-ground concrete ballasting.

FTL were project architects for the 21-acre Olympic Centennial Park which provided a focus in the heart of downtown Atlanta for all the athletes and visitors. This free facility attracted daily crowds of up to 250,000 people and contained several venues which were open to the public long into the night. The Centennial Park's major facility was the AT&T Global Olympic Village, a 9000 square metre complex composed of four main parts, three of which were relocatable building structures – the fourth was a central covered stage area made primarily from rented scaffolding and staging components (Fig. 12.27). This venue was the focal point of the complex and faced out to an open arena for more than 100,000 people. It was flanked on each side by the main new buildings, twin membrane-covered, arched pavilions containing restaurants, meeting areas and a public international telecommunications facility where athletes and visitors to the games could telephone home. To the rear of the stage area, between these two buildings, was the relocated Cadillac Mobile Theatre (see Case Study 12b) now used for a multimedia display event by the pavilion's sponsors, AT&T.

Owing to the vast numbers of people that would use the complex and the nature of the site, which was reclaimed inner-city land, temporary concrete foundations were built for the reusable buildings. However, because of the lightweight

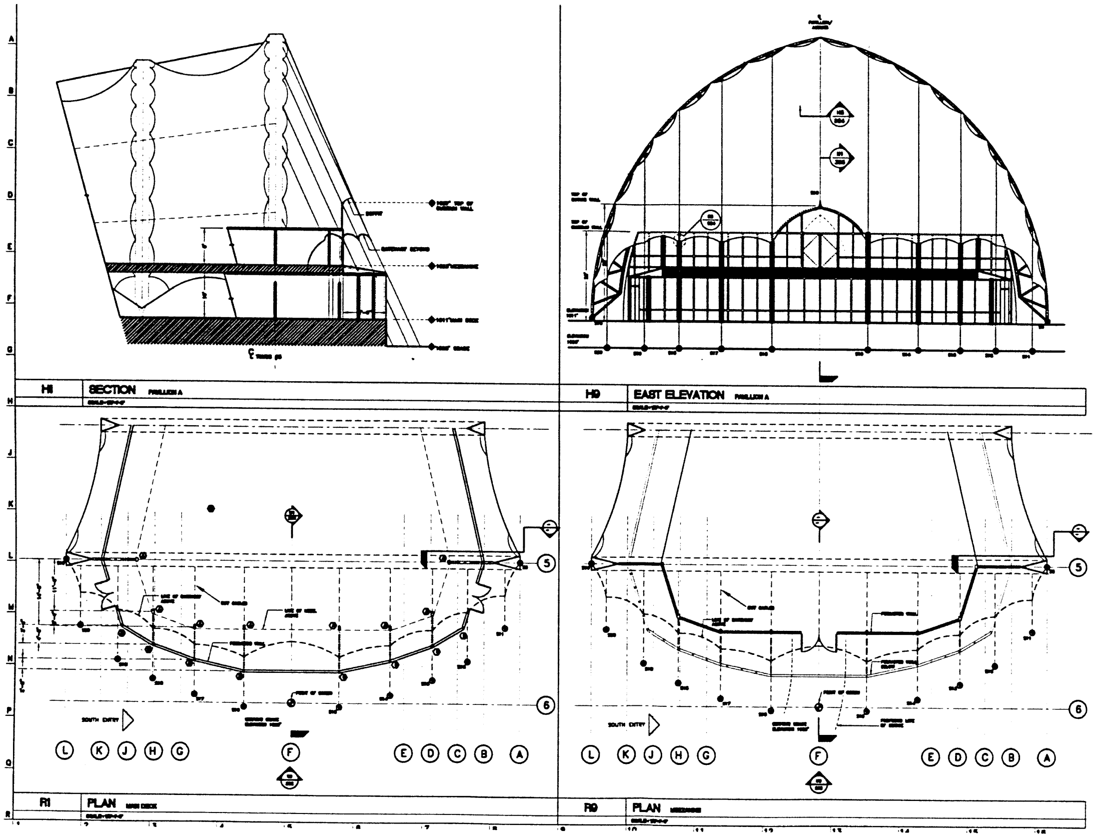

Fig. 12.31 Plan, section and elevations of the pavilion end wall.

nature of their superstructure, these could be much smaller than would normally have been required for a venue of this size. The twin pavilions form the largest relocatable enclosed building that FTL have made, covering more than 4500 square metres on two floors. Each pavilion is made from five prefabricated curved steel portal frames, delivered in sections, assembled at ground level, and dropped into place by crane. The longest arch is 27 metres from tip to tip. The frames were stabilised longitudinally by eight continuous cables which were tethered in the ground at either end and then tensioned (Figs 12.28, 12.29). Only the smallest end frame required cross-bracing to support the full height glass curtain wall above the entrances. Further movable glass walls, two storeys high, encircled the buildings (Figs 12.30, 12.31). The interiors featured relocatable elevators and high-quality lighting, video and audio equipment either fixed directly to the trusses or in special pods suspended below (Fig. 12.32). External walkways were constructed from standard steel scaffolding systems and timber decking, and included a dramatic curving second-storey bridge that linked the two pavilions. The buildings' fabric membrane was utilised as an entertainment feature, with

Fig. 12.32 Pavilion interior

Fig. 12.33
The Olympic Centennial Park.

images from Olympic events and live concerts projected onto it using a complex computer-controlled system that distorts the images so that they appear correct to the viewer, even though they are projected onto a curved surface (Fig. 12.33).

This temporary city, enlivened by interactive communications and human activity, was constantly active during its limited life. An integral part of the design concept was that it had the potential to be dismantled and perhaps reassembled in a different form at a different geographical location – a potent realisation of the dreams of architectural activists of the 1960s and a stimulating glimpse of what a future urban environment might be like.

Further reading

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Voodoo Lounge Stage Set

Date: **1994–1995**
Client: **The Rolling Stones:** Mick Jagger and Charlie Watts
Architect: **Mark Fisher and Jonathan Park**
Engineer: **Atelier One:** Neil Thomas
Consultants: Lighting: **Patrick Woodroffe**
Contractor: **StageCo BV, Belgium;** Inflatables: **Air Artists, Norfolk, UK;** Cobra Head: **Tomcat, Texas, USA;** Cobra Neck: **Sheetfabs, Nottingham, UK**
Cost: **$4 million**

The Division Bell Stage Set

Date: **1993–1994**
Client: **Pink Floyd and Show Director Marc Brickman**
Architect: **Mark Fisher**
Engineer: **Atelier One:** Neil Thomas, Richard Bentley
Consultants: **Rehearsals Project Manager:** Richard Hartman; **Production Manager:** Robbie Williams
Contractor: **StageCo BV, Belgium**
Cost: **$4 million**

Popmart Stage Set

Date: **1997–1998**
Client: **U2**
Architect: **Mark Fisher**
Engineer: **Atelier One:** Neil Thomas
Consultants: **Show Director:** Willie Williams; **Video Director:** Monica Caston; **Tour Director:** Jake Kennedy
Contractor: Steelwork: **StageCo BV, Belgium;** LED video wall: **SACO, Montreal, Canada and Lorrymage, Belgium;** Cladding: **SP Offshore Composites, UK;** Cladding track: **Triple E Ltd, UK**
Cost: **$9.5 million**

Bridges to Babylon Set

Date: **1997–1999**
Client: **The Rolling Stones**
Architect: **Mark Fisher**
Engineer: **Atelier One:** Neil Thomas
Consultants: Lighting design: Patrick Woodroffe; Video direction: Dick Carruthers
Contractors: **Brilliant Stages, UK**
Sub-contractor: Main stage: **Tait Towers;** Curtains: **Landrell;** Inflatables: **Air Artists, Norfolk**
Cost: **$4 million**

Mark Fisher describes himself as a technological optimist whose interest in temporary and transportable structures began during his training at the AA where he was influenced by the activities of Archigram and Cedric Price. There he created some inflatable structures that had much in common with the experimental architecture that was being produced in Europe at that time by groups such as Missing Link and Coop Himmelbau. Shortly after graduation this led to further work designing the stage set for the science fiction movie 'Zardoz'. The creation of temporary stage sets for rock music events also began at the beginning of the 1960s as the popularity of musicians such as Elvis Presley, the Beatles and the Rolling Stones meant that shows began to move outside conventional concert halls into sports arenas and natural amphitheatres, sometimes in locations remote from conventional services. These early outside concerts used amplification and lighting designed for use in primarily static situations, barely adequate for this much greater task, and it is questionable if sound quality or visual experience met with the expectations of the concert-goer. During the late sixties and early seventies a network of specialist companies began to emerge to meet the more ambitious demands of the concert promoters, developing new equipment and techniques specifically tuned to the requirements of large outdoor events. They introduced new portable amplification, lighting, and staging techniques and, because the equipment had to be relocated for each concert, transportation and erection services.

Musicians' ambitions for increased stage presence and a more spectacular show had expanded with the increased diversity and complexity of music type and its developing importance as a cultural and fashion statement. Perhaps most significant was the vast financial rewards that could be generated by the most popular acts – the music business had become a huge and important industry. Producers, promoters and record companies have now become highly competitive, professional organisations which produce large, spectacular shows and employ a wide range of specialised consultants, contractors and manufacturers.

In 1983 architect Mark Fisher and engineer Jonathan Park formed a multi-disciplinary team to service the design aspects of stage erection. Fisher now practises independently, utilising what he describes as 'fearless' engineering assistance from designers such as Neil Thomas from Atelier One whom he first met when he was working for Tony Hunt (Hunt designed one of the earliest UK outside rock festival stages, the Isle of Wight in 1969). His commissions for this type of work are won in much the same way as in conventional practice, in that designers are sought out because they have been involved in earlier successful projects of a similar type. Building up a good track record is important. The main clients are the musicians who are of course at the centre of the show. However, a production team with financial and operational managers are also involved from the very beginning. In this sort of project, the clients have big ambitions which are informed by their awareness of other productions. The most important performers wish to create a bigger and better show than any done before, though in Fisher's experience they have few detailed conceptions about how this might be achieved. Usually the clients give him a vague direction on which to develop themes and ideas which he will then develop into a 'pitch'.

Voodoo Lounge Stage Set

In 1989 Fisher was contacted to discuss ideas for the Rolling Stones 'Steel Wheels' show which would tour for fifteen weeks and attract a total audience of three million people. Mick Jagger had ideas for a stage set which had the appearance of a technological city. He went to three designers whom he knew had experience in the sort of large-scale project that a Stones tour would demand. After a series of competitive presentations he selected Fisher's ideas, presented in drawing and model form, for a seemingly aged megastructure retrofitted with new technology. Inspired in part by the work of science fiction authors such as William Gibson and film set designs by Ridley Scott and the real structures of oil refineries and rocket launch pads, Fisher created an apparently semi-realistic (yet wholly fantastic) 100 metre wide by 25 metre high backdrop for the band's show (Figs 13.1, 13.2).

Specialised show equipment must be incorporated within the stage set, in this case a 500 kilowatt public address system with massive stacks of speakers, one hundred computer-controlled moving lights and tracking spots and more than two hundred fixed lights. A closed circuit television

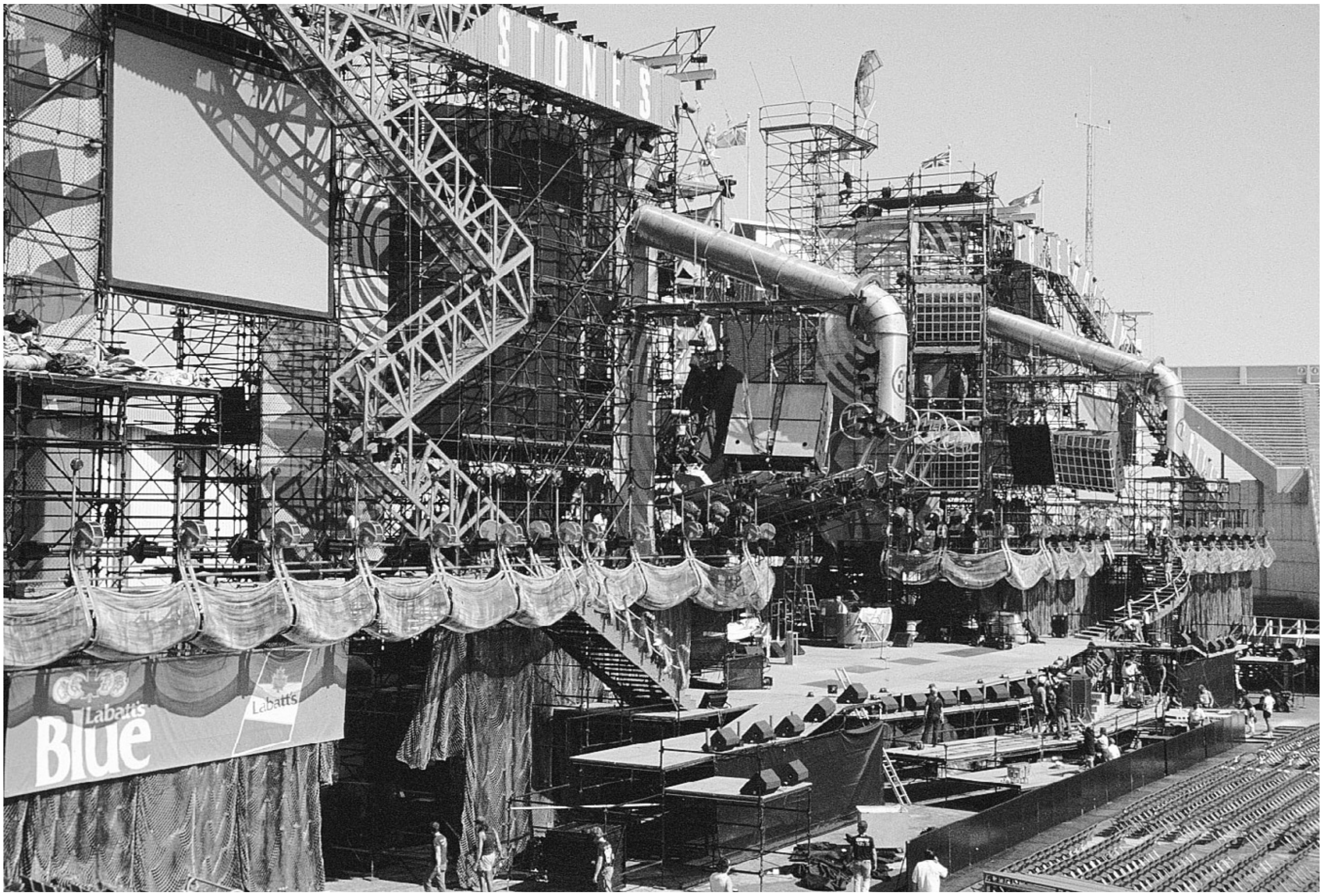

Fig. 13.1 Rolling Stones 'Steel Wheels' tour set, Mark Fisher, 1989.

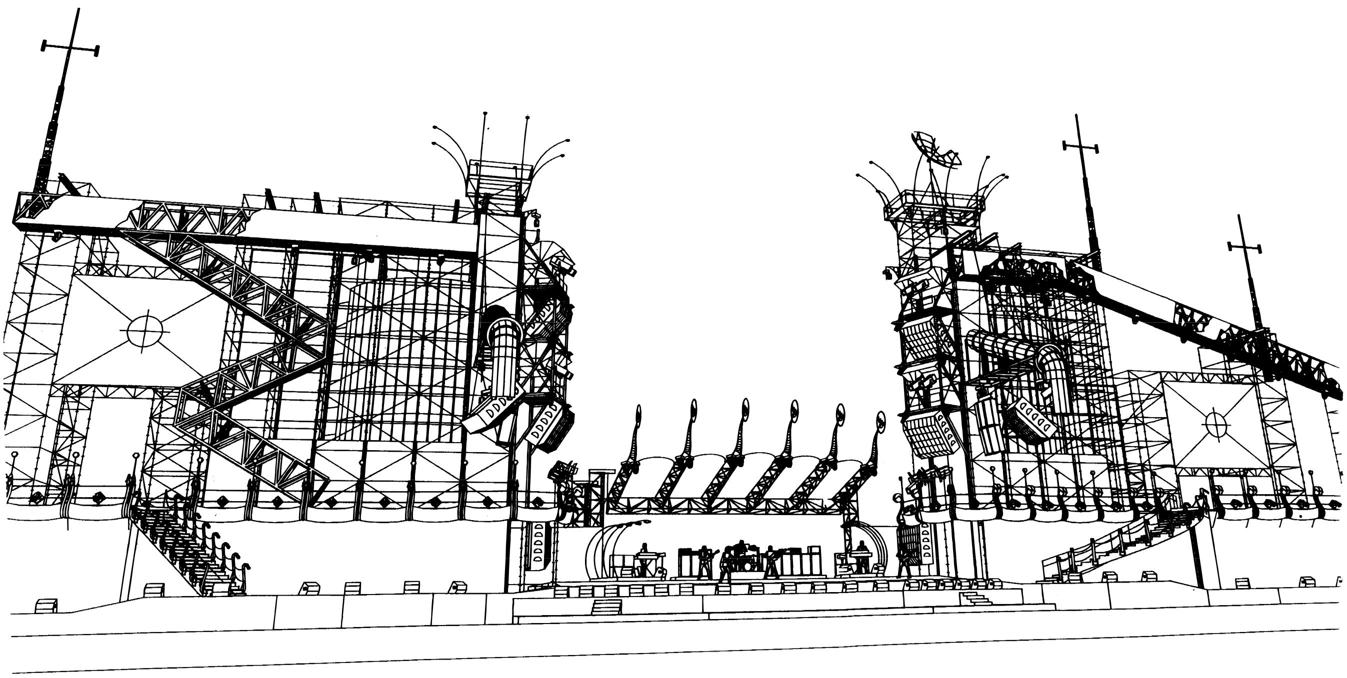

Fig. 13.2 CAD drawing of the 'Steel Wheels' tour set.

Fig. 13.3 Rolling Stones 'Voodoo Lounge' tour set, Mark Fisher and Jonathan Park, 1994.

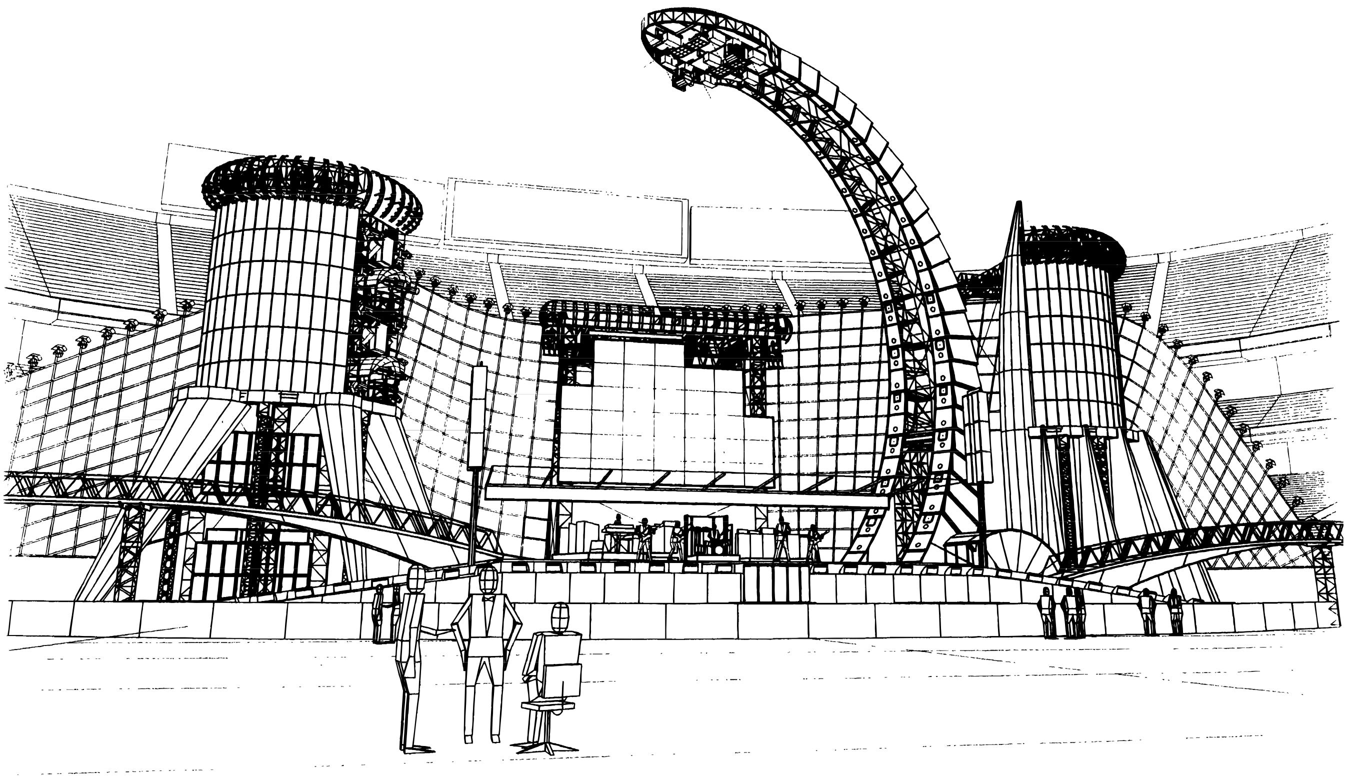

Fig. 13.4 'Voodoo Lounge' tour set, CAD drawing of the audience elevation.

system delivered images to two giant video screens. Fireworks shows and giant, instantly inflatable 'Honky Tonk Women' figures were used as well as 'exploding' and 'burning' stage structures. Though the scale of such a show is remarkable, it is made even more so by the fact that the entire package must be transportable. The 'Steel Wheels' set was seen as a ground-breaking design in that it attempted to reflect aspects of the real world in the fantastic setting of a stadium concert tour.

Logistical arrangements are crucial. Each show design consists of two major strategic elements – standard commercially available rental components and dedicated elements, created specifically for the show or owned by the musicians. A careful strategy is employed to manage a complex itinerary in which shows must take place only a few days apart and sometimes many miles distant from each other. In the case of the 'Steel Wheels' show a scaffolding substructure was devised, the basic components of which were obtained at the outset of the tour and transported in sixteen trucks from venue to venue. These standard components were all returned to the hire company after the last show. Four teams of fourteen crew members worked with a seventy-strong local scaffolding crew over the fifteen-week tour, each team building eight or nine frames in total. There were two complete sets of amplification, special stage components and lighting rigs which were transported between alternate venues to arrive thirty-six hours before the concert. A dedicated crew of forty together with a locally hired team of eighty stage hands erected this equipment. The specialised band and video equipment and dedicated crew of forty arrived twenty-four hours before the concert to set this gear up, and the band members with a personal entourage who assisted with make-up, security and wardrobe, arrived on the afternoon of the performance. This entire production procedure was reversed immediately after the concert was over.

The Rolling Stones 1994 'Voodoo Lounge' stage set had a completely different appearance to that made for the previous tour, yet in some ways it can be perceived as a development from the 'Steel Wheels' project (see Fig. 13.3). Technically it benefited from the constructional processes developed by Fisher for the Pink Floyd 'Division Bell' tour designed in the previous year. Mick Jagger and Charlie Watts, the main band members concerned with the design, contacted Fisher because of the success of his previous work. The band once again wanted to reflect a near future environment, this time influenced by the developing information age. Though he realised the manifestation of a society intimately involved in communication technology might be difficult to represent in physical form, Fisher developed the concept of another city vision, though this time one that incorporated sensuous metallic flowing forms. These forms still created the image of an interactive complex, though with a different character than the frenetic uncontrolled technopolis of the previous set's imagery. Metal-surfaced columns and walls with flying bridges formed the main part of the stage, over which a giant metallic snake towered. A giant video screen formed the centre piece of the stage. Pyrotechnics were used at the beginning and end of performances and at one point twenty-two inflatable characters emerged to populate the set which was thereby transformed into the giant 'Voodoo Lounge' club (Fig. 13.4). This $4 million stage set once again used extensive standard components combined with a number of specific pieces which helped create the unique image for the show. The largest special component was the snake structure which was manufactured from components sourced in Belgium, UK, the USA and Canada and erected there in an enclosed stadium for dynamic testing. Its stability was achieved by the use of steel tanks filled with water to provide substantial temporary foundations. The 'Voodoo Lounge' set was erected 180 times in the twelve-month duration of the tour.

The Division Bell Stage Set

Even though the size and effect of the Rolling Stones' sets were impressive, there can be no doubt that it is the charisma of the band that charges their shows and attracts the fans. The Stones are still enthusiastic about their image as a rock and roll band and they and their designers perceived the sets as backdrops to the performance and an aid in communicating the band's activities simultaneously to a much larger audience. The philosophy that drives the design of the Pink Floyd sets is quite different. Pink Floyd are perceived by their fans as cerebral, ground-breaking, progressive musicians whose work contributes to their understanding of the world. The Pink Floyd shows have a history of

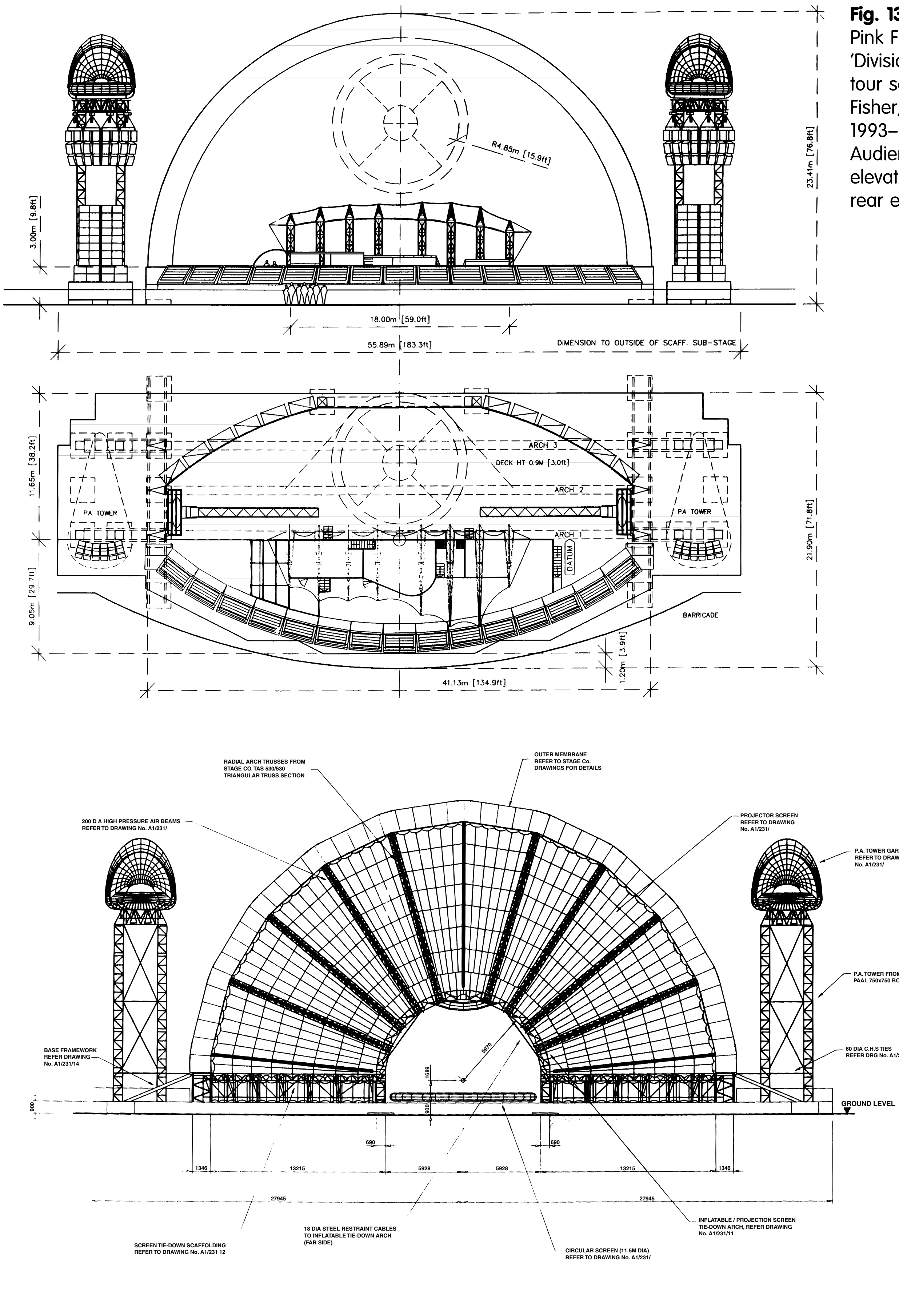

Fig. 13.5 Pink Floyd, 'Division Bell' tour set, Mark Fisher, 1993–94. Audience elevation, plan rear elevation.

being a complete ‘experience’ that begins with the music but extends far beyond its immediate inspiration. For decades they have used audio-visual experiences in their live shows, not just to complement the music but also to inform the performance – film, sound effects, and physical elements have long been a component of the live Pink Floyd experience.

Pink Floyd’s record album ‘The Wall’ was also conceived as an animated cinematic feature film based on caricatures by the satirical cartoonist Gerald Scarfe. As a celebration of the reunification of Germany and in order to inaugurate the Memorial Fund for Disaster Relief, a single performance of ‘The Wall’ was given in Berlin’s vast Potsdamer Platz to be seen not only by the 290,000 people present but by a vast world-wide television audience. This unprecedented event included former Pink Floyd member Roger Waters and more than 200 performers, including a new group of musicians specially rehearsed for the show, a symphony orchestra, a choir and a marching band. The main feature of the performance was a 168-metre long, 25 metre high wall braced by 508,000 kilograms of scaffolding and steelwork and constructed of 2500 1.5-metre long polystyrene blocks. During the first half of the show a large part of the wall was erected by trained stagehands so

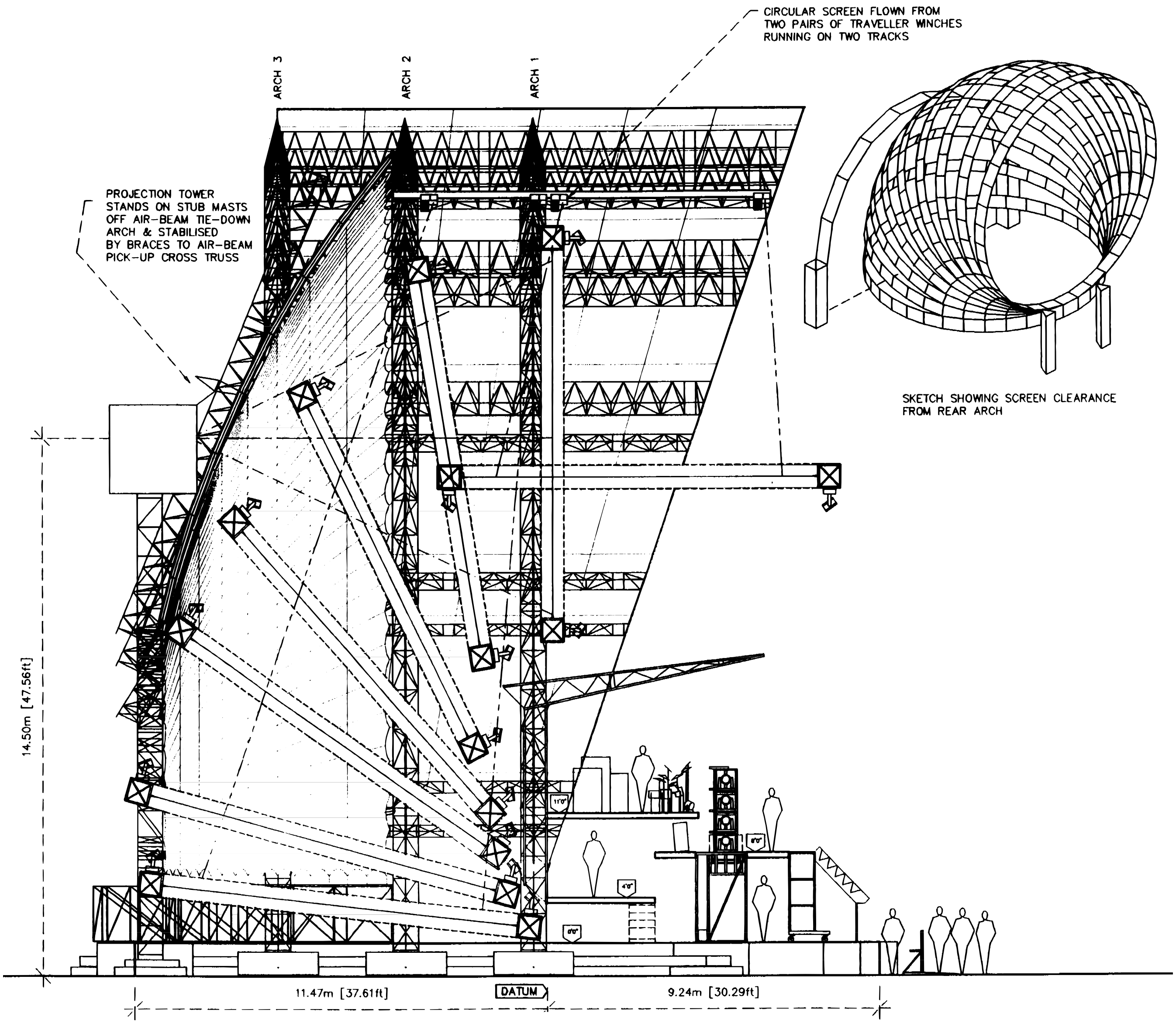

Fig. 13.6 ‘Division Bell’ tour set, cross-section showing moving rear screen.

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that it could form a screen upon which scenes and events related to the message in the music could be projected. Giant inflatable characters were manipulated by tower cranes as the performance progressed, culminating in the destruction of the wall at its end. Though this particular show was not intended to tour, it is an example of a dramatic temporary construction which established a new relevance for a particular location through the creation of a single dramatic event and indicates the ability of temporary architecture to trigger a dramatic change in people's perception of an important location.

Fisher believes that his most recent set for Pink Floyd is his most interesting piece of work in architectural terms because although it utilises techniques and strategies which have been developed specifically for the creation of stage design, they may be applicable in other fields of temporary construction (Fig. 13.6). The client's show director, Marc Brickman, had the idea of the band performing in a gateway to another world where images and events related to the music could be enacted. Fisher, once again working with engineer Neil Thomas, devised the idea of a great 40-metres wide semi-circular arch that would surround a curved backstage projection screen (Fig. 13.7). To provide a high-quality image for some of the films used during the performance, a second circular screen would be moved into place above the stage from behind the performers whilst the show was in progress. Because of its large size the main arch would not provide shelter for the band's delicate equipment, so a second transparent shelter was also

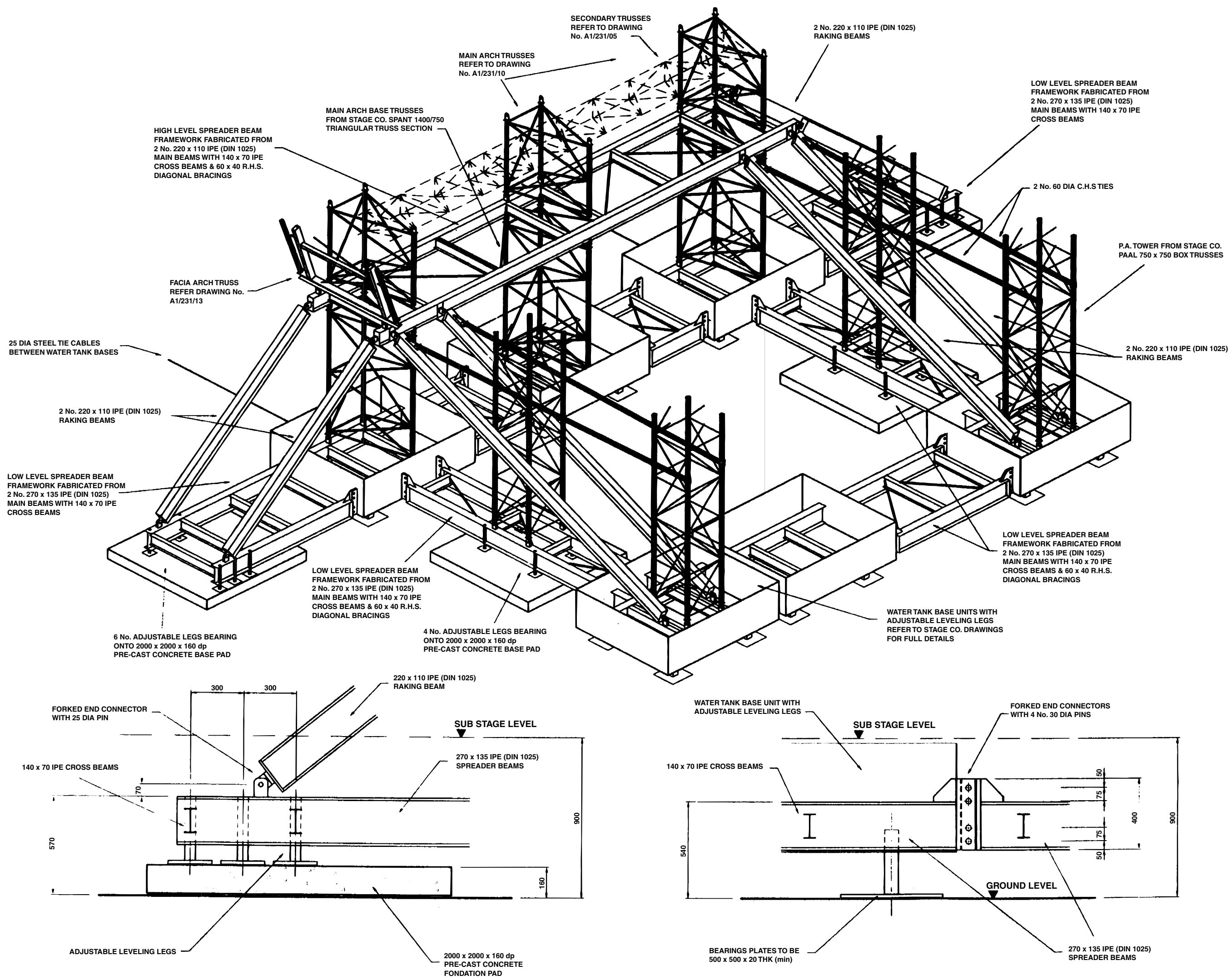

Fig. 13.7 'Division Bell' tour set, movable foundation details. Adjustable legs are stabilised by water tanks.

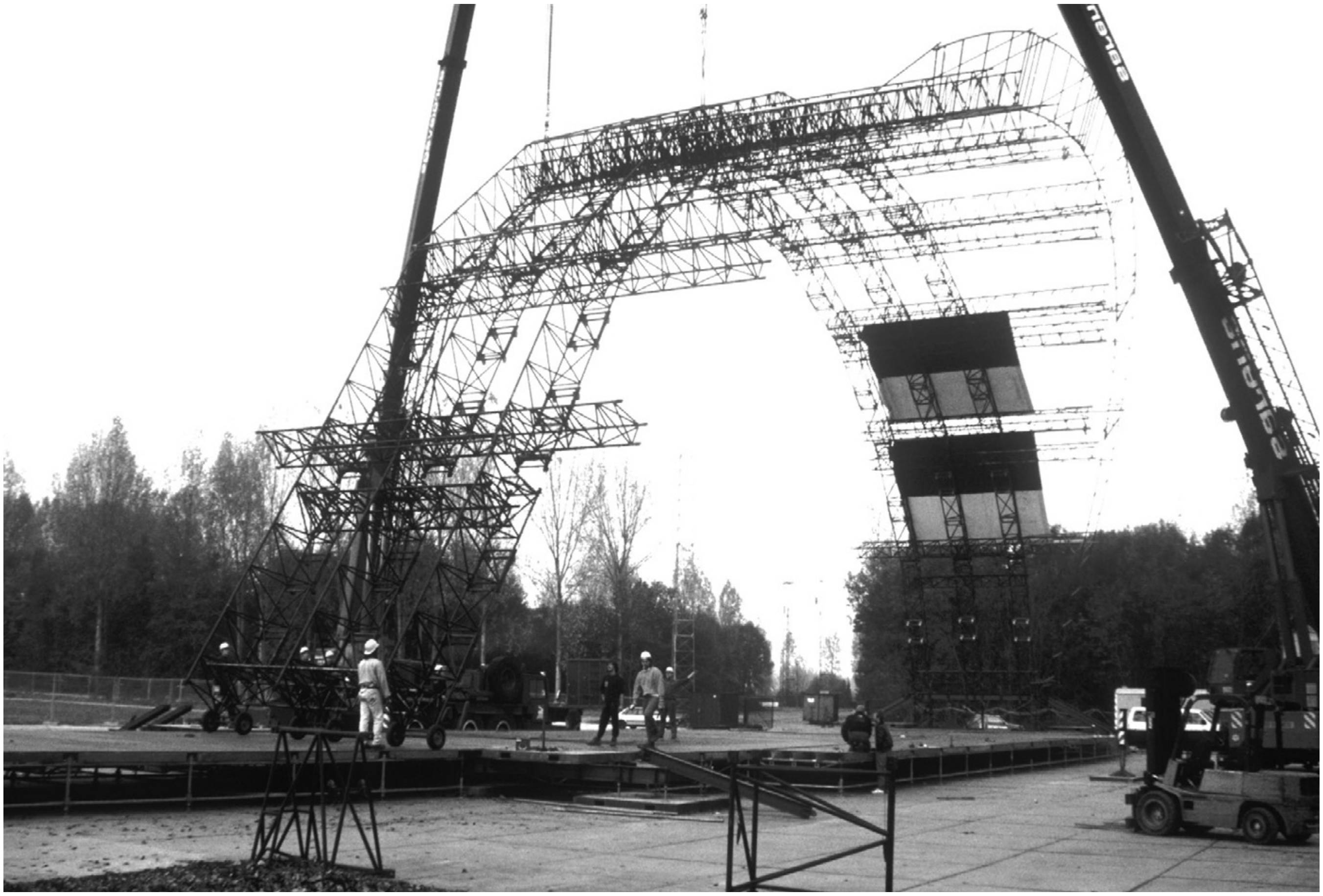

Fig. 13.8 Erection of the main arch structure.

necessary for protection from the rain. Various events would take place during the show to punctuate the performance – floating inflatable pigs (famous landmarks from a previous Pink Floyd show, 'Animals') moved about the stage before disappearing in a crash of flames, and a giant mirror ball that was elevated in the centre of the stadium projected slivers of light into the audience until it too appeared to self-destruct in a flash of light. The performance used a number of effects developed from other technologies – industrial lasers that give a much wider beam were used here as lighting effects. Film and slide effects developed for use in the cinema and special effects incorporating pyrotechnics and mechanical devices were used live for the first time in a concert situation (Fig. 13.10).

This complex performance system had to travel from event to event, averaging fifteen shows a month for its eight-month tour, frequently changing venue with each performance. In order to achieve this schedule the main structure was built up from standard components that had been reconfigured to give the unique shape required for this specific show. Three separate main stage assemblies were required to meet the schedule. It was important that the unique arched shape of the set could be achieved with primarily standard components in order that most of the structure could be rented rather than specially manufactured and abandoned when the tour was over. When the tour moved from North America to Europe the last show in Montreal was only seventy-two hours away from the first show in Lisbon. All the specialist components were air-freighted between the two cities. The modified standard components could be erected into the huge arch in just seven hours, each triangulated framed piece hinged to its adjoining member and swung into position (Fig. 13.8). The water-filled bases were adjustable to enable the structure to be levelled on any site (Fig. 13.7). The back wall was supported by high-pressure inflatable

Fig. 13.9 Rear of the set. The rear wall has a twinned structure of radial steel lattice beams and air beams that brace the membrane projection screen.

Fig. 13.10 A wide range of ancillary structures for the production facilities are also erected in the main audience area.

Fig. 13.11 The concert in progress with the movable high quality projection screen in place.

tubes which had the advantage of simple speedy deployment, though they also had the associated risk of catastrophic deflation (Fig. 13.9). The amplification towers were erected at each side of the arch and fixed into its structure to provide added stability. The 'Division Bell' set was wind tested in model form before construction, and was trial erected three times in order to eradicate problems that might be met on tour. Though minor details were changed at this stage no alterations were made in the conceptual form or its construction and the project was completed on time and on budget.

Popmart Stage Set

The Popmart tour set was created by Mark Fisher for the hugely successful Irish rock band U2. The set utilises consumer images familiar from the urban strip and the suburban mall – a golden arch, a cocktail stick and a billboard – though each are hugely inflated to stadium size (Fig. 13.12). Fisher describes it as a 'touring supermarket, a satire on fin-de-siècle consumer decadence'. This appropriation of 'vulgar' product branding is reinforced by the moving images shown on the 'billboard' screen, which, as well as the band, includes specially commissioned animations of work by pop artists Roy Lichtenstein, Keith Haring and Andy Warhol, reinvesting the original symbiosis between popular culture and fine art with cynical meaning. During the show the video images are predominant – the performers, though intermittently blown-up to huge dimensions above, are for the most part minute figures at the screen's base. Only once do they make more intimate contact with the audience

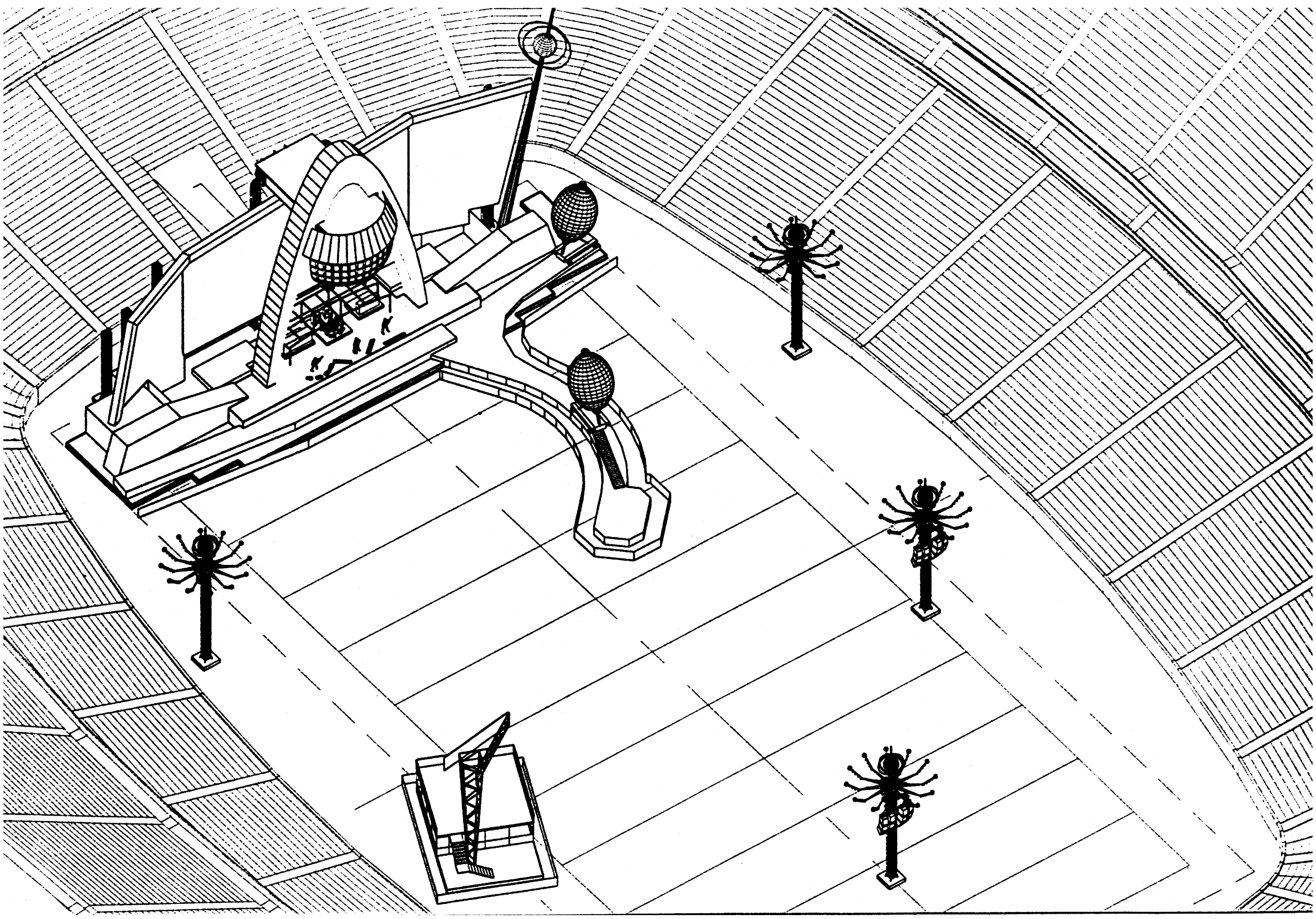

Fig. 13.12 Popmart stadium layout computer drawing.

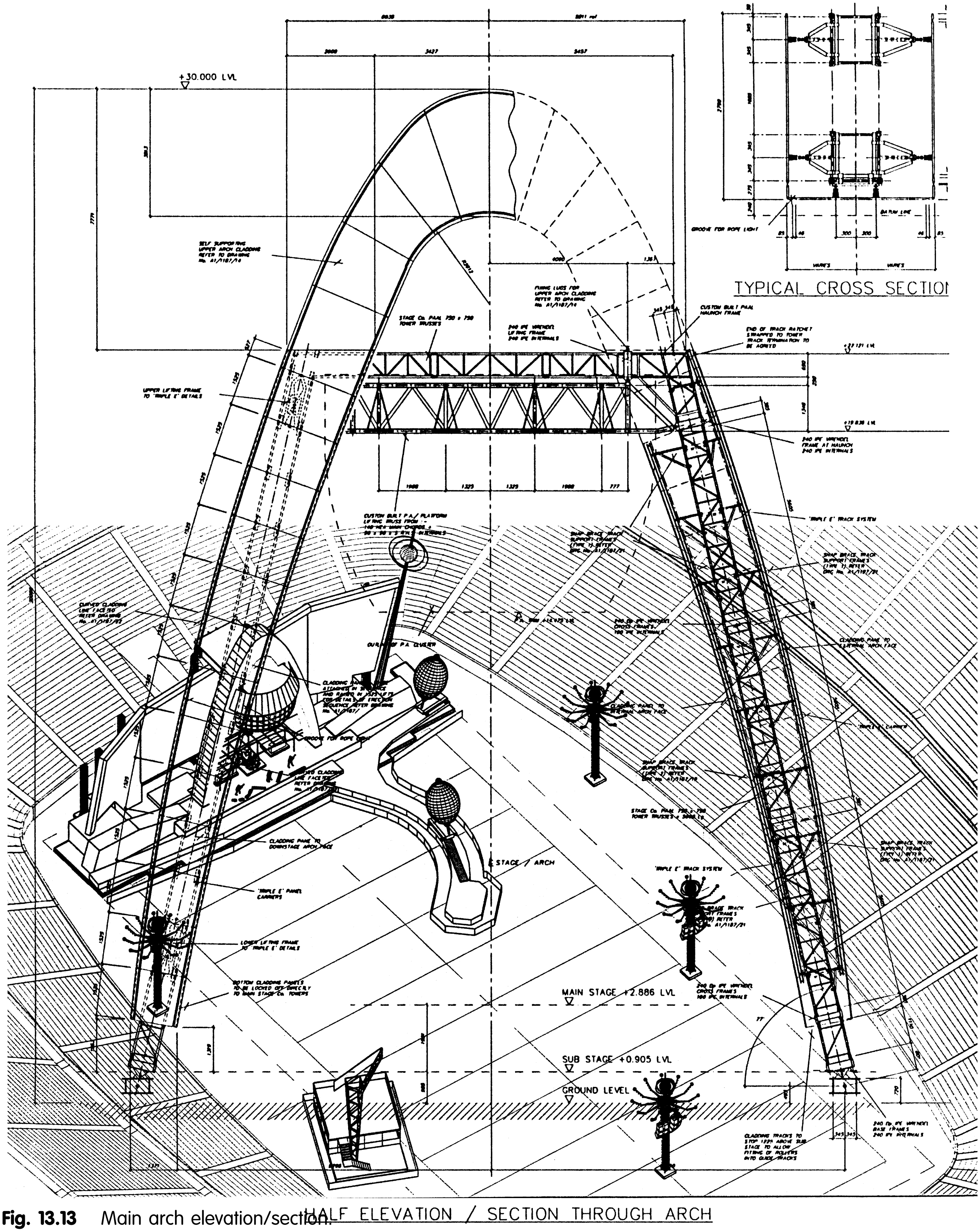

Fig. 13.13 Main arch elevation/section.

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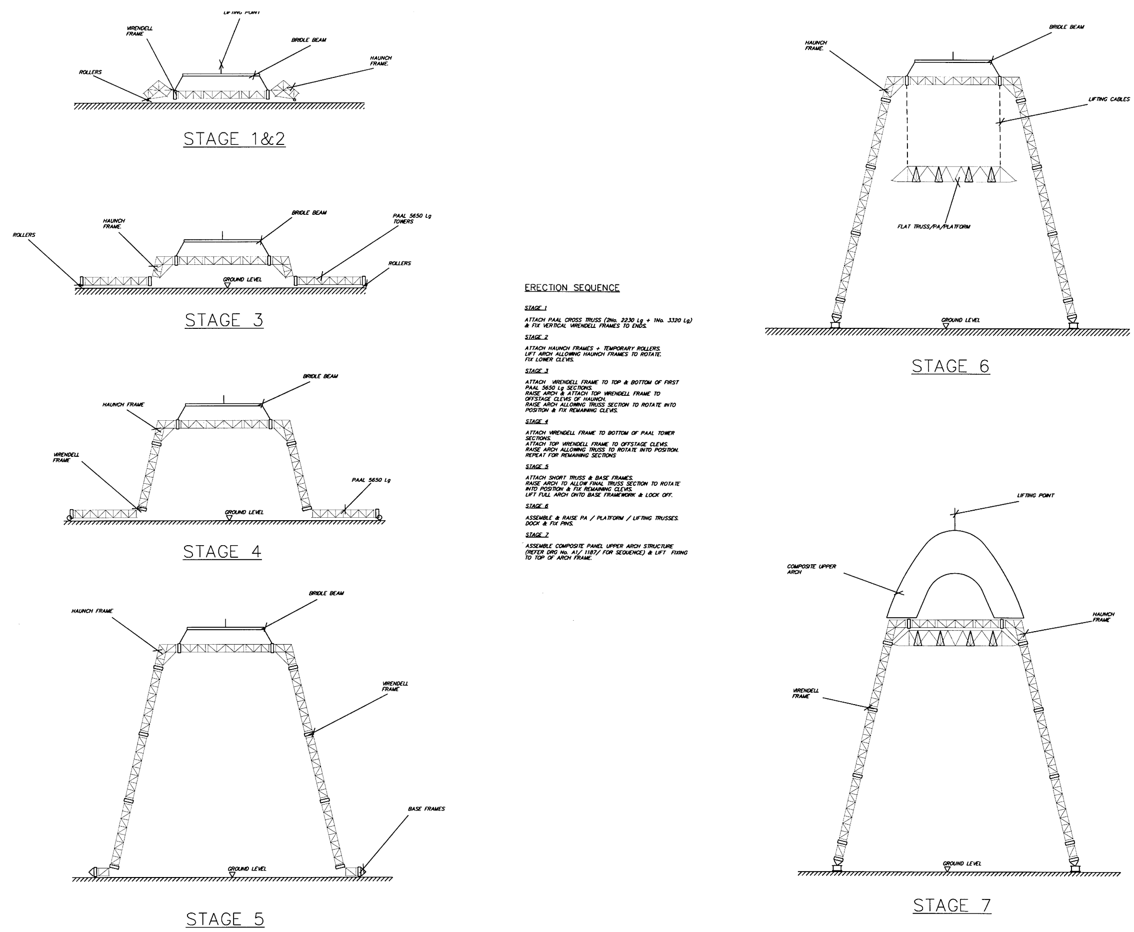

Fig. 13.14 Main arch erection sequence.

when late in the show they are transported inside a mobile lemon to a special stage 50 metres out into the crowd. The band's intellectual critique of the multi-national commercial organisations that dominate the world are at the core of the show's image though, of course, it is precisely this system that makes their international success possible.

The style and content of U2's image and music differ widely from Fisher's other clients such as the Rolling Stones or Pink Floyd, and it is not surprising that the band desired a totally different image for their show. However, despite the very different image that 'Popmart' presents, much of the set incorporates the same constructional and logistical strategies used in the creation of Voodoo Lounge and Division Bell. The stage is constructed from a rented system of components provided once again by the Belgium specialist contractor StageCo BV; indeed the water-ballasted foundations for the golden arch are the actual ones used in the Pink Floyd set. The 30-metre high arch structure (Fig. 13.13) is a major visual feature but it also supports 18 tonnes of amplification equipment and 6 tonnes of lighting. It consists of a rigid portal frame constructed of sectional verendell trusses that, when assembled, form straight legs 20 metres high. The horizontal cross-member is assembled on the ground and the legs are then attached to either side. As the central section is lifted, the legs move in on rollers to their final position. The next leg sections are then attached and the process is repeated (Fig. 13.14). The crown of the arch is a separate component constructed from composite panels and once its assembly is complete at ground level it is placed on top of the portal with a crane (Figs 13.15, 13.16). A heavy-duty track system is used to fit the composite cladding panels to the upper part of the legs, enabling this assembly work to also be done at ground level for extra speed and safety. In order to allow a quick turnover between venues there are three main structure assemblies and three arch crowns that travel separately. There is, however, only one set of lower panels which are amongst the last items to be fitted before the show begins and the first items to be disassembled after the show is over.

Fig. 13.15 Arch assembly.

Fig. 13.16 Arch panel assembly.

The musicians are conveyed to the thrust stage inside a 12-metre high revolving fluorescent lemon built onto a self-propelled truck with a top speed of 3 mph (5 kph). As the moment in the show approaches when the move to the small stage takes place, the fluorescent covering is lifted off to reveal the mirror-ball lemon which revolves at 10 revolutions per minute. It opens by 'peeling' the top half upwards and then the band, who stand inside on a stationary platform, descend to the stage on a hydraulically actuated staircase.

A 30-metre high 'cocktail stick' (Fig. 13.17), made from aluminium trusses clad in orange coloured Lexan, pierces a glass fibre pimento-stuffed olive. This flamboyant image frames one end of the billboard which is the most dominant part of the set and also the most technically innovative. Fisher first had the idea for the billboard screen in January 1996 when he saw a prototype Light Emitting Diode (LED) screen demonstrated. Green LEDs have been in use in electronic equipment for 20 years and red followed shortly after but, owing to technical reasons associated with semi-conductor chemistry, the economic manufacture of the other colours has been more difficult and it was only in 1995 that blue became commercially available. Full colour requires green, red and blue light sources to operate properly and, in the case of a LED screen (Fig. 13.18), the light sources have to be arranged in groups to simulate a single pixel that can simulate colour light and shade. The 'Popmart' screen is 50 metres wide and averages 16 metres high – the one million LEDs are contained within a surface area of 700 square metres in 125,000 groups of eight. The pixel groups are placed 75 mm apart on narrow aluminium tubes

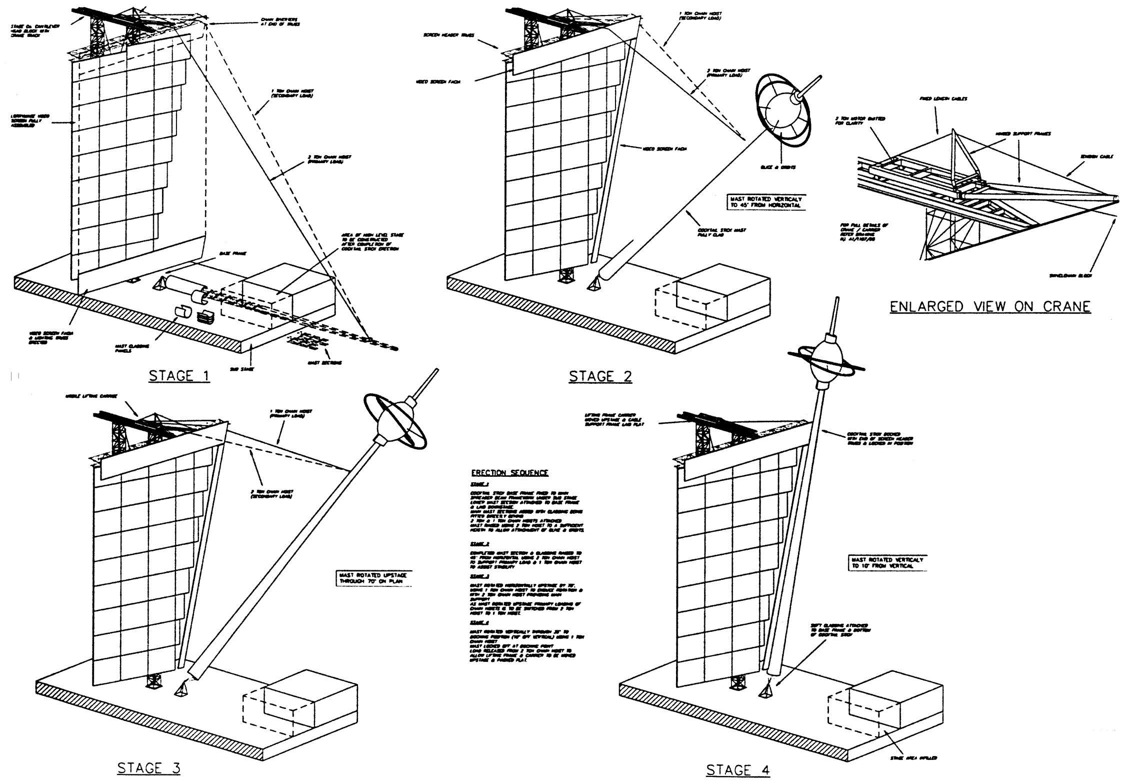

Fig. 13.17 Cocktail stick erection sequence.

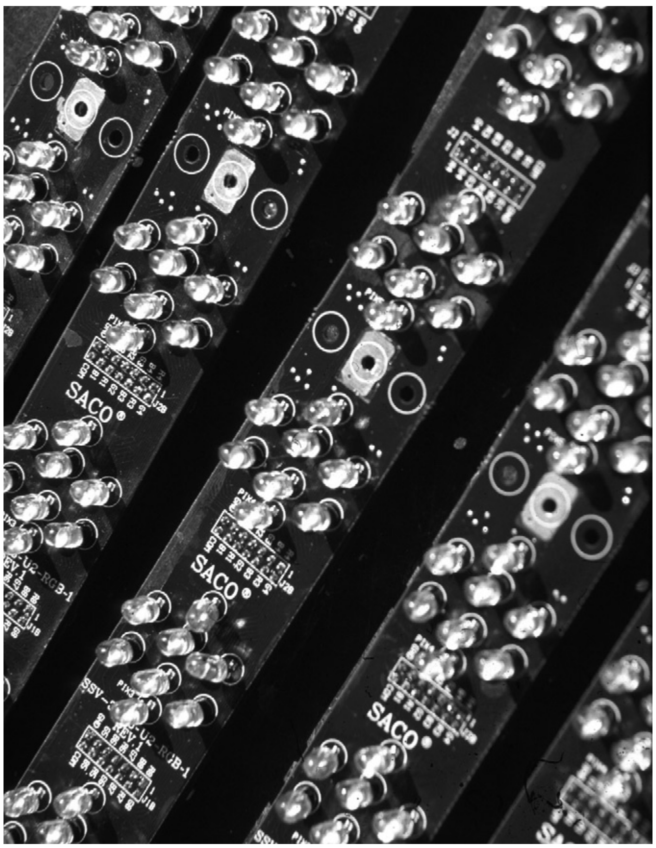

Fig. 13.18 Light Emitting Diode (LED) matrix.

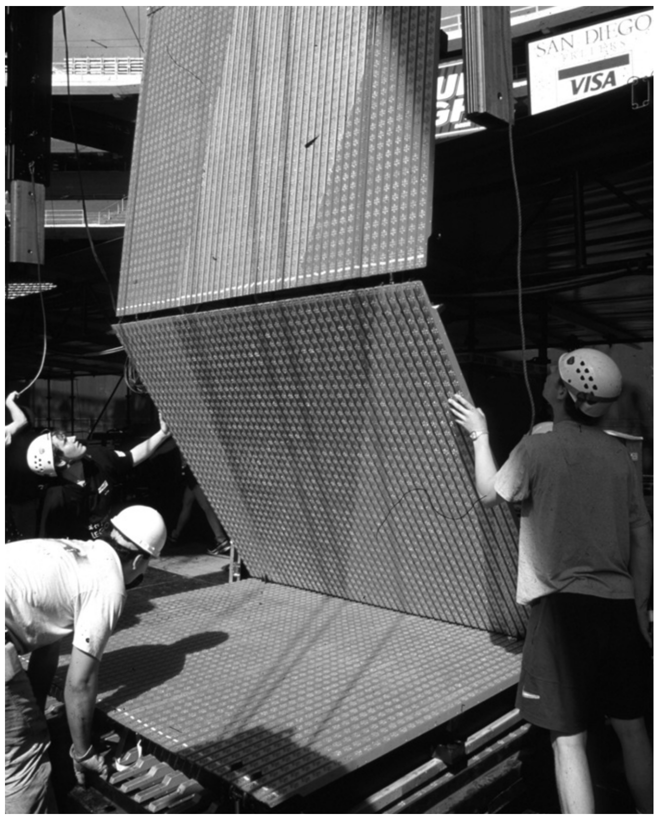

Fig. 13.19 LED screen panels being deployed from their transportation cart.

Fig. 13.20 Daytime view – the painted Popmart logo is clearly visible.

made up into 2-metre square panels. Early in the tour problems were caused in the screen operation by rainwater penetrating the LED housing – this was solved by encapsulating its electronic components in a military specification silicon resin. The panels are hinged together at top and bottom and stacked in a cart for transportation (Fig. 13.19). For assembly, the cart is wheeled to the bottom of pre-erected aluminium extrusions suspended from the truss which forms the top of the 'billboard' screen. Each panel has lugs which fit into the extrusion and locate it firmly as it is lifted by chain hoist into place. Because the screen is composed of frame rather than solid elements, in certain lighting conditions it becomes translucent and images being played on the screen intermingle with the real world behind. When the LED screen is not operating the metallic red and gold 'Popmart' logo (which is painted onto the frames) dominates (Fig. 13.20).

This technologically innovative screen, developed especially for this project, cost more than US $6 million to manufacture (though it was bought back for reuse by the company who manufactured it after the tour), and not surprisingly only one was constructed for transportation to every venue. The screen can be erected in 6 hours, and the arch steelwork (which packs into twelve trucks) can be ready in 8 hours. As the set is a free-standing structure (Figs 13.21, 13.22) it must meet international safety standards, including earthquake resistance and winds of up to 110 mph. As with all rock sets, all the elements are actually only brought together for 4 to 5 hours at a time, enough for testing and for the show to take place. The remainder of the time it is either being assembled, disassembled or in transit.

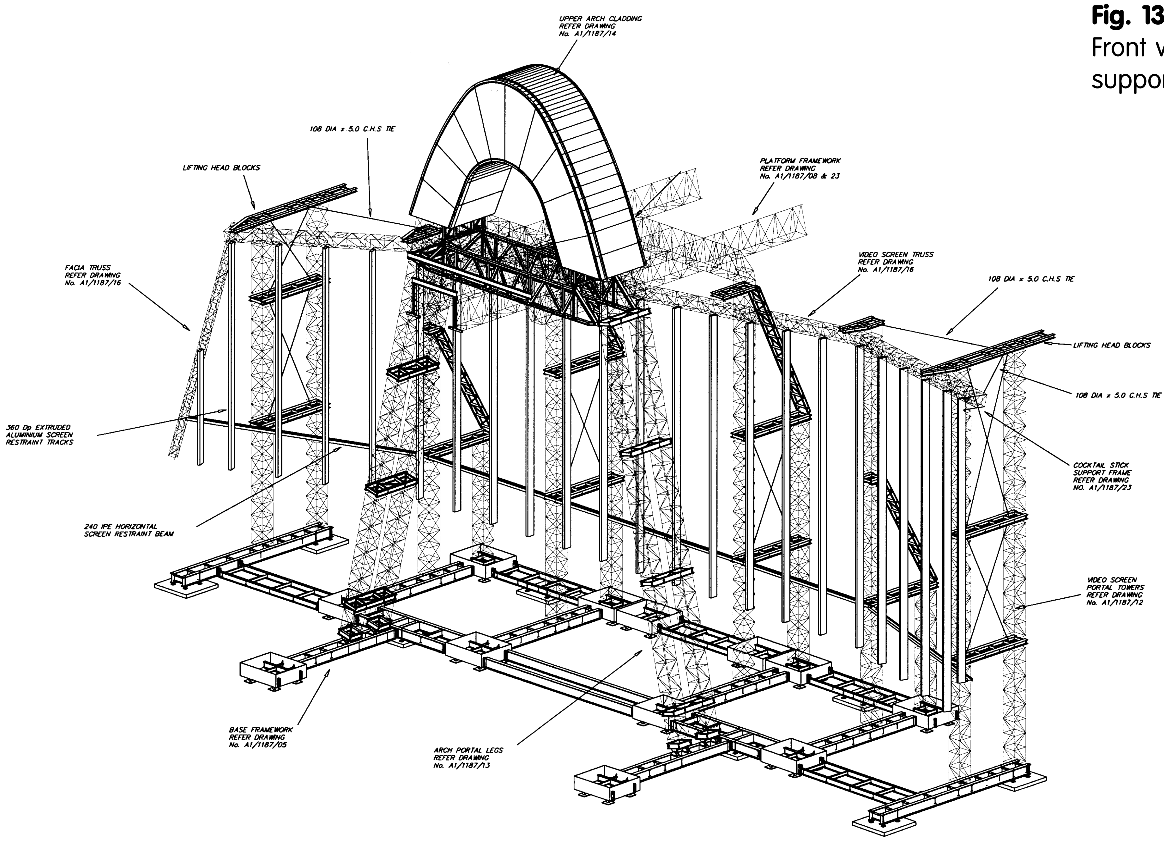

Fig. 13.21
Front view of main supporting structure.

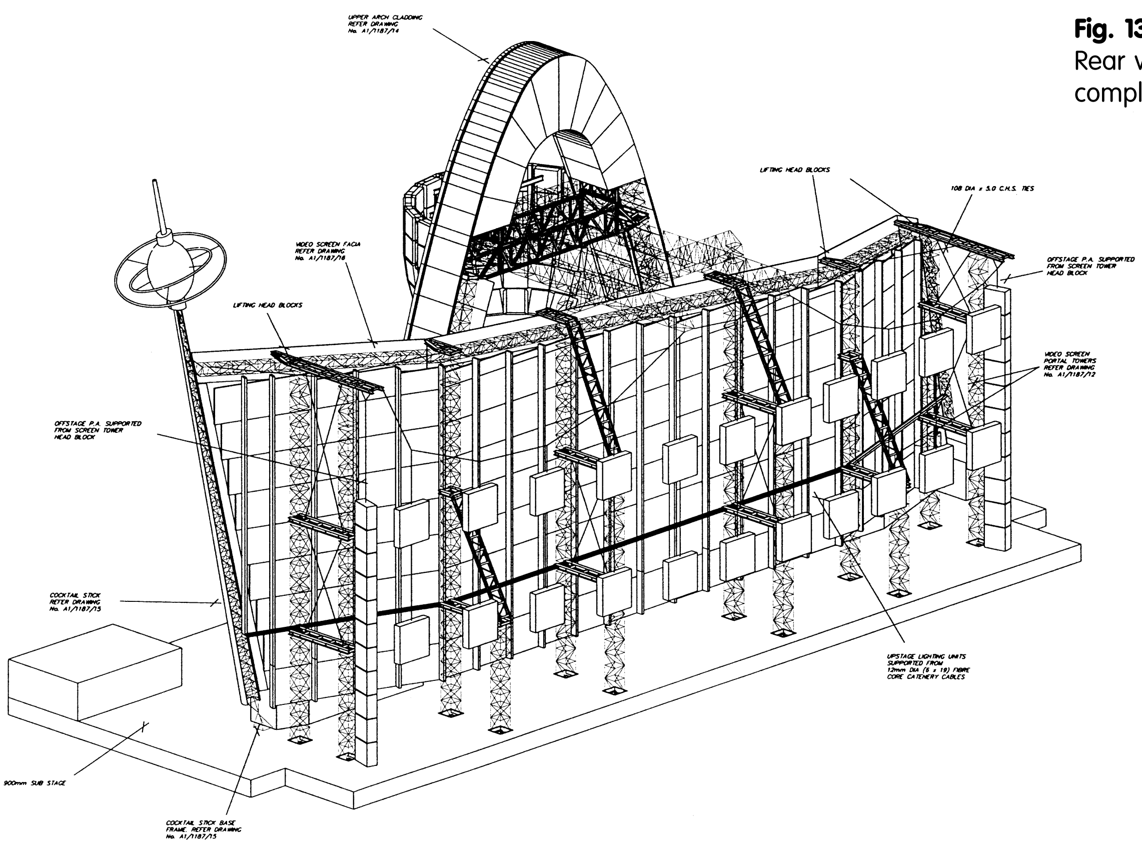

Fig. 13.22
Rear view of complete set

Bridges to Babylon Stage Set

When 'Popmart' first appeared in 1997 it was called by some the 'Everest' of concert industry set design, however, things happen fast in show business and it was just 5 months later that the show was surpassed, at least in some significant areas. Surprisingly, the new peak was a set for one of the longest lived touring bands in existence, the Rolling Stones, who still tour regularly after 35 years in the business. The Stones first approached Mark Fisher a year before the beginning of their projected 100 date world tour. Early ideas for the show's theme were based on the seven deadly sins, with initial concepts for an inflatable figure for each sin, but this soon metamorphosed into a more general theme based on opulence, power and riches. The key image at this time was the idea of 'Gold' not just as a colour but as a representation of these things. Fisher investigated a range of sources for the design including the Baroque, ancient Egyptian architecture, and the futurist sculptor Bocchione, suggested by Gerard Howland, head of design at the San Francisco Opera. The final concept was brought to fruition by a wide range of people, including the band, particularly Charlie Watts and Mick Jagger, the lighting designer, Patrick Woodroffe, and Jagger's friend, the playwright Tom Stoppard. The end result could not be further removed from the knowing self-awareness of the U2 set – it is a visually impressive, dynamic, metamorphosing, over-the-top creation that celebrates the centrepiece of the Rolling Stones show which is undoubtedly the live experience of the band themselves (Fig. 13.23).

The set is designed to reflect a consecutive series of stages in the progress of the live show, built around different phases in the band's history and different moods in the character of their songs. It is also designed to facilitate the simple, yet effec-

Fig. 13.23 Bridges to Babylon stage set.

Fig. 13.24 The bridge to the 'B' stage.

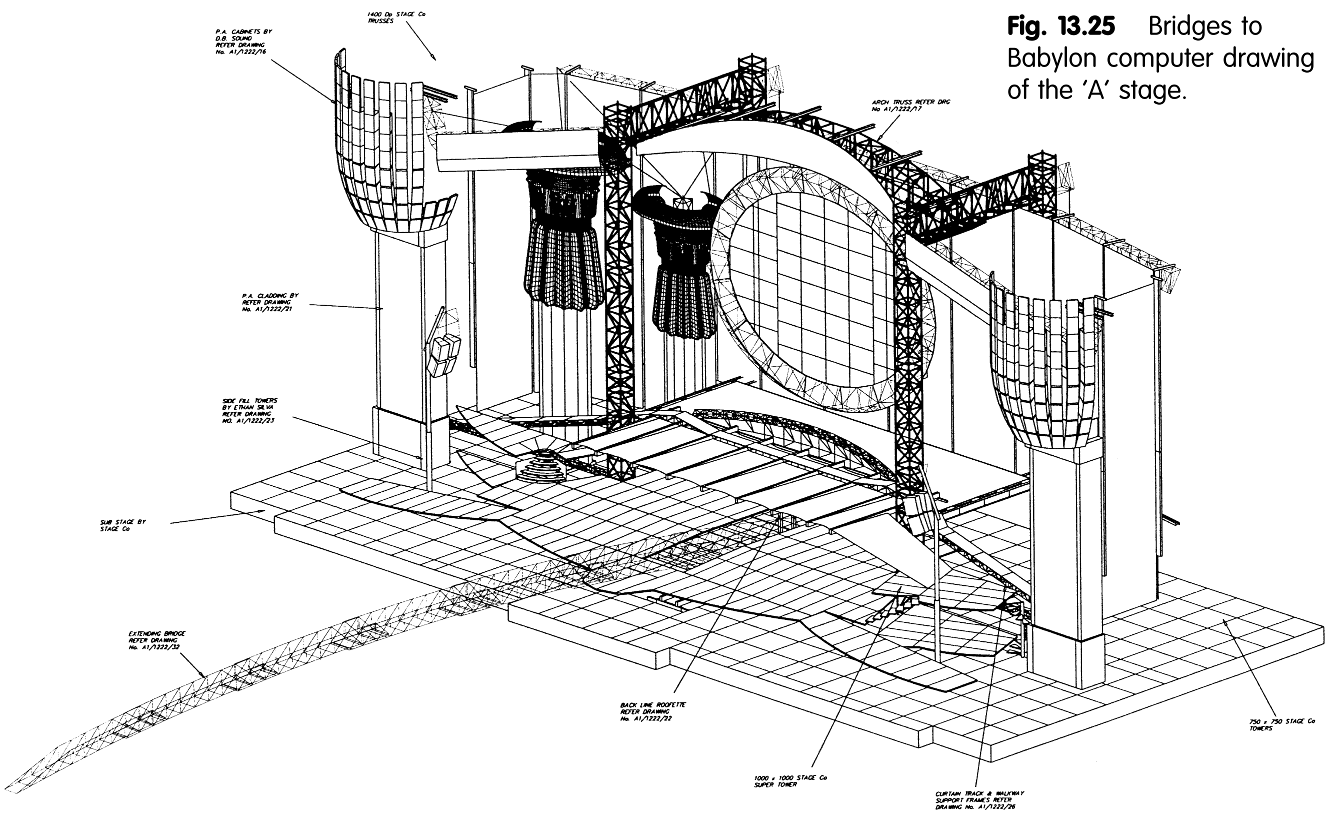

Fig. 13.25 Bridges to Babylon computer drawing of the 'A' stage.

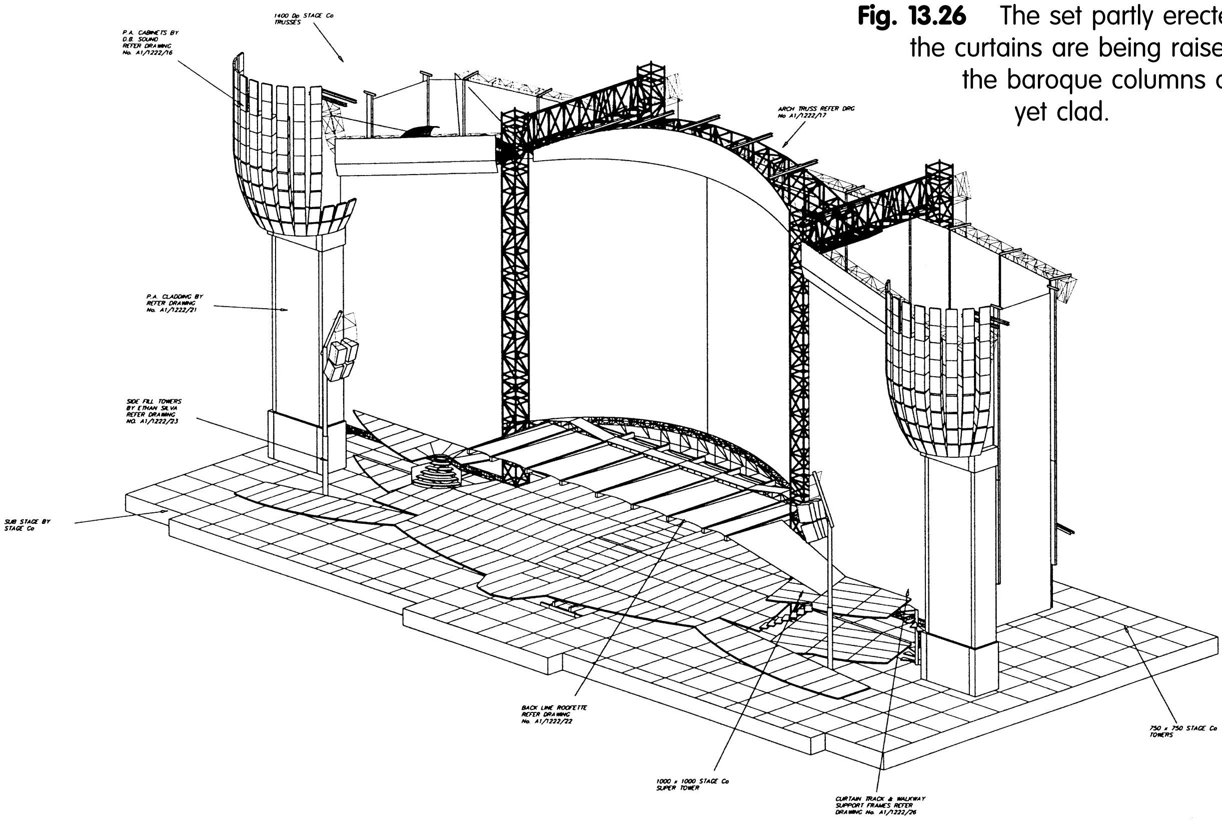

Fig. 13.26 The set partly erected – the curtains are being raised and the baroque columns are not yet clad.

tive, strategy to start with a bang, proceed with a bigger bang and end with the biggest bang of all. A crucial decision was to create two stages, the 'A' stage being the main 'proscenium arch' structure which faces the audience and around which most of the concert and the special events are based, and the 'B' stage (Fig. 13.24), a much smaller 'club'-type structure 50 metres out in the centre of the crowd providing the Stones with their first experience of playing 'in the round'. It was decided to make the presence of this stage secret from the audience so that the element of surprise when the band descended into their midst would signal a crucial culmination point in the show. The look of the show was also influenced by the introduction of two smaller mix towers, lighting on the left, sound on the right, rather than the conventional large central box. This meant that the centre field remained clear of the usual large mixing structure and enabled the possibility of novel spotlight angles from two, rather than one remote audience-based location.

The 'A' stage (Fig. 13.25) consists of a 54-metre wide by 26 metre deep platform with a 25-metre high triple masted framework supporting a range of ornamental elements, some architectural, some sculptural (Fig. 13.26). The PA towers masquerade

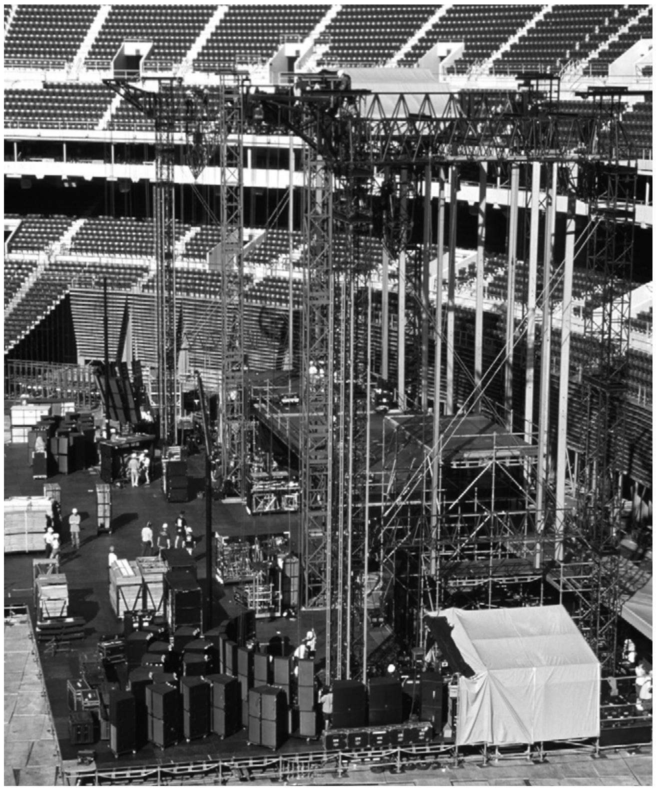

Fig. 13.27 The stage's structural frame – the column-head PA speakers are stacked ready for assembly.

Fig. 13.28 The curtains remain closed for the first part of the show

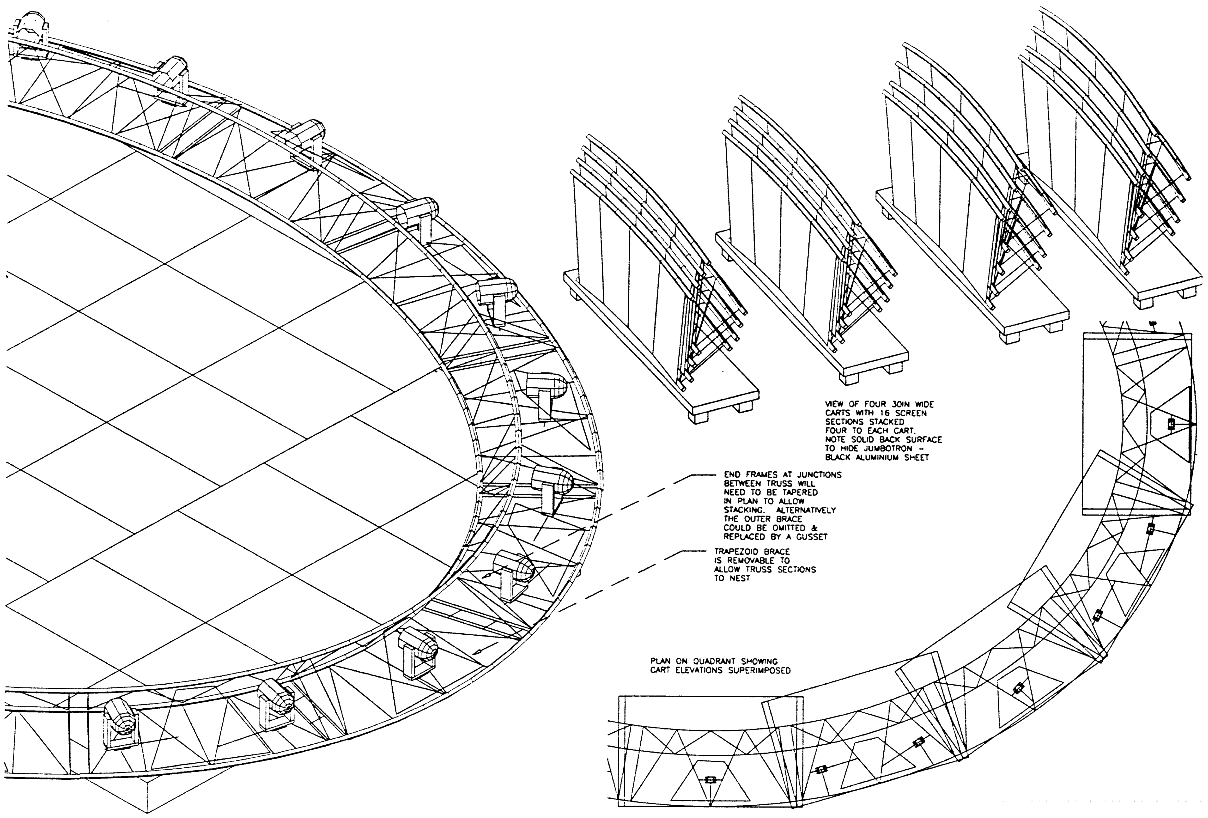

Fig. 13.29 The specially designed surround to the Sony JumboTron screen showing the cart stacking arrangements for transportation

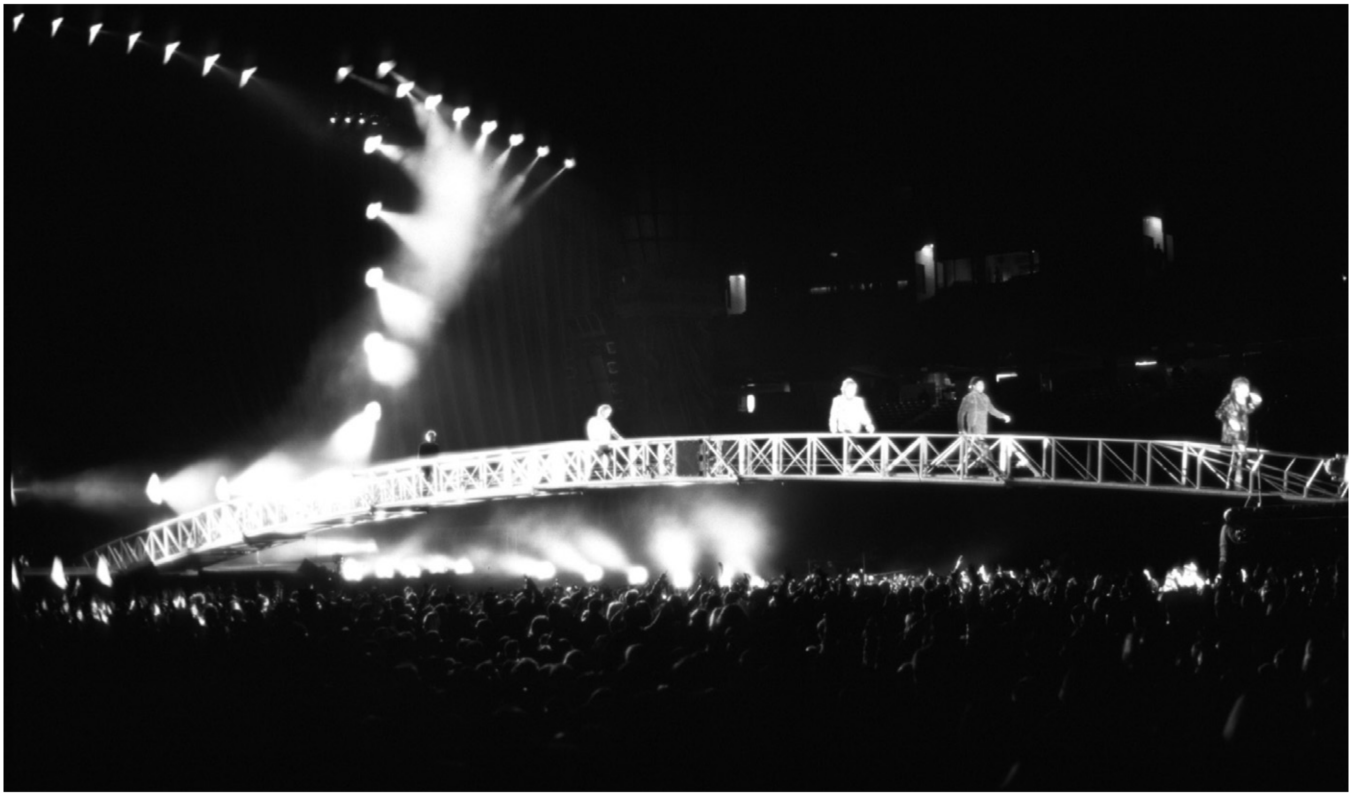

Fig. 13.30 The Bridge.

as exaggerated column capitals and the video screen is a giant ellipse with an opulently decorated rim (Fig. 13.27). Pyrotechnics are used, particularly at the beginning of the concert when a giant meteor appears to come out of the screen, fly towards the stage and explode out into the audience. Giant curtains made by Landrell are used to conceal various parts of the set to heighten the sense of development in the show. These were carefully designed to appear freely swagged in winds up to 40 mph (68 kph) and were hung with tracks adapted from racing yacht rigging design (Fig. 13.28).

For the moving image part of the show an LED screen was considered, however, the higher quality, though smaller in size, Cathode Ray Tube (CRT) system using the commercially available Sony JumboTron was deemed more appropriate. Nevertheless, the screen used was still the biggest one toured to date, 10 metres high by 13.5 metres wide (Fig. 13.29). This screen is used to show specially prepared images and animations created by the video director Dick Carruthers as well as the live performance. In a special live link-up with the Stones' web-site, made possible by ISDN lines brought to each venue, fans not at the concert can vote for a specific song to be included in the set and then watch it live on their computer screens anywhere in the world. One legacy from the original seven deadly sins theme was the creation of Miss Sloth and Mrs Gluttony, two 15-metre high inflatables. These are used in quite a different way from the Voodoo Lounge characters which swayed and pulsated in the wind – the inflatables for Bridges to Babylon are modelled to appear like solid sculptures and are deployed behind the curtains or in blackout so their presence is only announced when they are fully formed, giving them a formidably realistic persona. Pneumatics are used in this way as an economic and logistically efficient method of creating a dramatic set piece.

Though the show is very much an assemblage of physical components and events rather than a single powerful idea and image, perhaps the most dramatic element, and certainly the most technically demanding, was the creation of the bridge that spanned the gap from the 'A' to the 'B' stages. It fulfilled several functions: a pragmatic way for the band to get to the remote stage, the added drama of a surprising event in the show, and as a

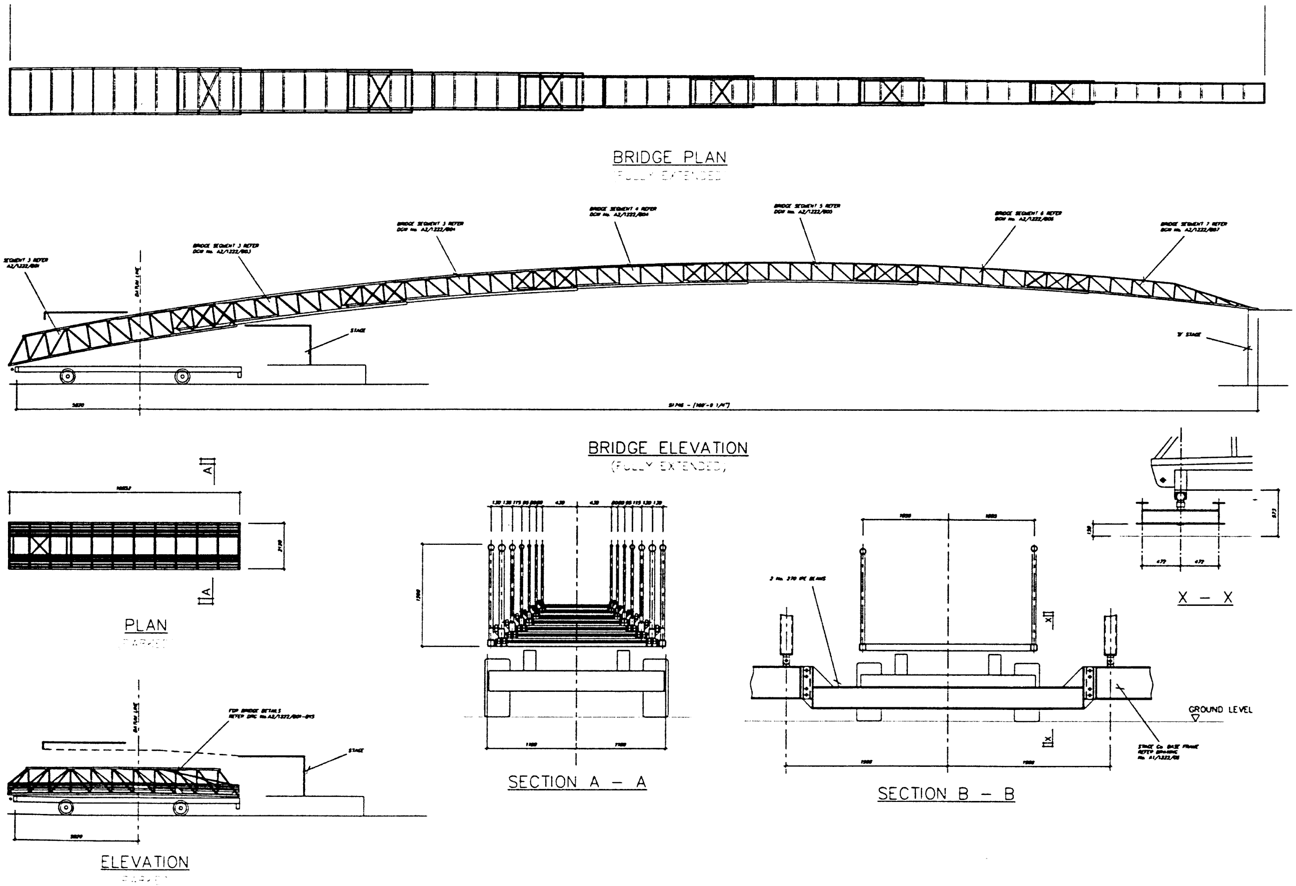

Fig. 13.31 Bridge construction.

symbolic physical realisation of the eponymous 'Bridge' (Fig. 13.29). This structure is not only heroic in its proportions, with an overall length of 52 metres and an unsupported cantilever of 43 metres, but also in its kinetic qualities – it is not a static object but extends from a secret compartment beneath the 'A' stage. When in transit around the world, moving from aircraft hold to tour truck, and tour truck to stage, it can be driven around independently as a 15-tonne vehicle propelled by four-wheel hydraulic drive and four-wheel steering. It consists of seven, 11-metre long, steel bridge sections that when in stored mode sit within each other like a fireman's ladder (Figs 13.31, 13.32). The bridge reveals itself to the audience with clouds of smoke and light and then tilts up 9 degrees into 'firing' position. A winch is then actuated to deploy the sections which extend simultaneously from the fixed bottom platform. The 6-metre square 'B' stage simultaneously begins to rise from its 600-mm stored height up to 4.5 metres to meet the bridge, the band walk across and then the bridge retracts and the 'B' stage drops down to its 2-metre high performing position. A counterweight for the cantilever is provided by the stage and the JumboTron above. Brilliant Stages made the bridge under the direction of Atelier One in just 16 weeks from concept approval. Not surprisingly, weight was a crucial factor in the cantilever sections and Aerolam carbon-fibre decking was used to keep it as light as possible. The construction of such a bridge was a feat of engineering which had not been tried before and it is commendable that it worked perfectly the first time it was used, although its arrival was slightly delayed owing to certification changes that would make its use possible in the USA.

The bridge assembly cost £1 million to manufacture and, not surprisingly, only one was made so this part of the show travels to every venue – the hasty getaway being one reason that it was designed to be self-propelled. There are three separate main stage assemblies, each requiring fourteen trucks to leapfrog to a third of the total

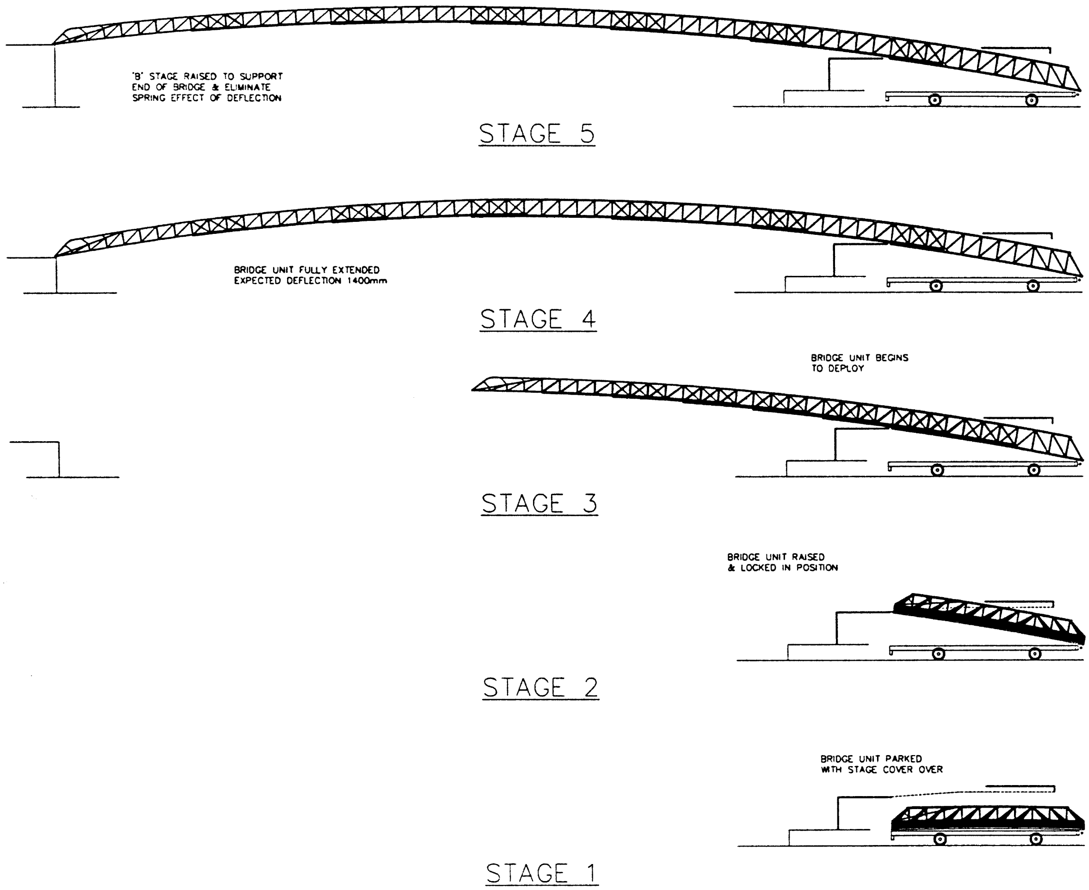

Fig. 13.32 Bridge deployment sequence.

venues. This show also transported its own dressing room supplies, furniture and other facilities so it could be as self-contained as possible. All the transport elements have been designed to fit inside a standard ocean container, the upper deck of a Boeing 747 or foreign transportation road vehicles as well as US trucks. In order to cut down as much as possible on the transportation load that must be carried from place to place, set carts and transportation dollies are often also used as construction elements in the show, for example as spotlight gantries and platforms. Despite such economies, thirty-two large vehicles, in addition to the fourteen trucks for the steelwork, are required to transport the show between venues. Fisher has continued work for the Rolling Stones designing their 'Lick' tour which opened in September 2002, with three deparate designs for studio, arena and theatres, allowing the band to perform their live show in different types of venues.

The proof of the success of Fisher's work is that his clients return to him for his conceptual and detailed design skills. As well as the Rolling Stones and Pink Floyd he has worked for U2, Simply Red, Bryan Adams, Whitney Houston, Tina Turner, Janet Jackson, Jean-Michel Jarre, George Michael and Stevie Wonder. As has already been stated, this sort of work leads to more of the same kind; however, Fisher is also working on other projects in related fields. He completed designs with Jonathan Park for special event stages at Expo '92 in Seville (though only one relatively modest one was built) and he has also worked on the 'Wizard of Oz' touring ice show devised by Barnum and Bailey and the Ringling Brothers. This show has toured since 1995 and had more than 3000 performances throughout North and South America and Asia. Though it will operate primarily within existing performance spaces, where none is available, it will utilise a transportable shelter which is currently under development. Fisher was the creative director for the Millennium show at the Millennium Experience Dome in London which ran every day during its year-long opening. He also filled the same role for the building's opening celebration event which featured more than 1000 performers.

The relationship between the creation of spectacular transportable stage sets and conventional architecture is complex. It is obvious that the sets have substantial architectural presence, use many of the same inspirations in their formal design and are seen by many thousands of people. However, it could be argued (and Fisher makes this point himself) that these designs are essentially two-dimensional, they are meant to be viewed by the audience, not used by them. The people who use the sets are the musicians and those who prepare the show. Ancillary accommodation such as toilets, showers, catering, wardrobe, make-up and video production suite are provided by portable trailers or specially designed vehicles. The actual sets modify their environments in a primarily visual and aural manner but other environmental interventions are minimal such as basic shelter from the rain for delicate equipment. These great touring shows are generally a summer event, when better weather can be relied on during the concert and erection and dismantling procedures. Though they are technically complex and often innovative in the use of lighting, video projection techniques and computer-controlled effects, they are loosely fitted into the set in order to allow quick assembly and dismantling and are therefore not fine tuned in the sense that the services of a building are. These stage sets are not critically inspected at close quarters but seen, often from a single viewpoint, from comparatively long distances. Fisher makes the point that in an age of such sophisticated technology the link between form and function has become obscured and in fact unnecessary – set structures can take any form, the more unusual the better, in order to achieve their main function of communication of a dramatic image related to the performers' musical and artistic ideas. In essence, all rock sets have the same programme though their appearance may be radically different. However, Fisher still believes that as in architecture, the quality of structure and form is reinforced if they are consistent and synonymous.

Despite the professional involvement of designers like Fisher, stage show design is still an area were amateurs are involved, either the musicians themselves bringing their own ideas to fruition or the 'drummer's girlfriend syndrome' where a designer is chosen not necessarily for what they have to offer but who they are. In these situations it is the specialist companies who provide the expertise to realise the project. In an industry where everything should at least appear fresh each time, it is often the rearrangement of standard components rather than the introduction of new ones that give that impression.

The budget for the projects are usually firmly established before design begins and the manufacture of the set, which may be as much as $4 million (though the Potsdamer Platz show cost $10 million) with up to half of that spent on special customised scenery, may only be a relatively small part of the total budget. Approximately half a million dollars is spent on the presentation of each show, with a complete tour costing $25 million. Cost control experts are appointed on a project basis in much the same way as the designer, and they also move from tour to tour in the same way. Contracts are not as complex as in conventional construction, often by letters of agreement based on a set of drawings which are less detailed than in the building industry. Because there is a great deal of repetitive work, contractors are familiar with the working methods and operation pattern of companies they have collaborated with before and this leads to mutual trust.

The design of these large transportable stage sets have significant differences from conventional construction. Many of the systems which are used have arisen specifically from the nature of the task, and been developed within the industry, though it is clearly possible that they might also be of use in the erection of conventional building projects. The time scale for creating these sets is often telescoped four months from design concept to completion is common. For this reason many of the usual attributes of conventional building are inappropriate. The production manager, lighting and effects designers, even the master rigger who will govern the erection team, take part in the design process from the very beginning. The use of specialist experience is crucial, not just engineers like Thomas who have a knowledge of new materials and techniques, but also specialist manufacturers and erection companies like the Belgian organisation, StageCo BV, who provided standard components and erection services for both the 'Voodoo Lounge', 'Division Bell' and 'Popmart' sets. A process concerned with the concept of what Americans call 'value engineering' is used, in which all those involved in the different areas that make up the show are involved in its overall design. The objective is to ensure that the constructional and logistical strategies which are most effective are coordinated for ultimate efficiency. Though each show must be unique, many standard components are used, though these may have been specially developed for the industry, often by the people who supply and erect them. A series of very experienced companies who are used to working with each other often bid for the same jobs and are familiar with the logistics of their task. Despite the short lead-in time, by the end of each job Fisher will often know by name each of the crew working on a particular project. This is a common feature of the relationships created during this sort of project and a mutual trust and understanding of the capabilities and requirements of each team member's role is a feature essential to the tour's efficient operation. Even though many pre-manufactured standard components are used, handicraft is still important, both in the preparation period when special scene assembly, inflatable manufacture, and lighting effects are made, but also as the show travels on the road when solutions to the inevitable running problems must be found on site, at short notice. In essence, the philosophy that the show must go on is as important for one as technologically complex as this as it has been in the past.

Further reading

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Colourspace

Date: **1972–95**
Client: **Various**
Designer: **Maurice Agis**
Constructor: **Maurice Agis**

Dreamspace

Date: **1959–2003**
Client: **City of Copenhagen Festival Committee, Denmark**
Designer: **Maurice Agis**
Constructor: **Maurice Agis**

The creation of architecture is not restricted to the creation of buildings. There are many alternative areas of creativity from which architecture may develop, some of which are more related to artistic expression than functional issues. Developments in architectural thought are almost always linked with parallel developments in the visual arts (and literature and philosophy) and many designers, crafts persons and artists see the architectural world as intertwined with their own fields. One of the strongest connections between fine art and the world of architecture is in installation art, an extended form of sculpture that creates a complete environmental experience. Whether they stand alone or are related to an existing space, these environments not only shape physical space but may also add movement, sounds and smell. Installation art attempts to reduce the boundaries between viewer and viewed and bring the artists' ideas to a situation where they can be communicated more directly. It can be said about almost any work of art that it does not exist unless it is in the presence of a human being, however, some artists now include the viewer's contribution as part of the work to increase its power and meaning. Environmental installation art is quite often temporary and/or portable in nature, as the power it has to transform well-known places, both urban and natural, is a recurrent theme of interest to many artists.

Maurice Agis was born in London in 1931 and studied sculpture at the city's St. Martin's School of Art in the early 1960s. The main body of his work is involved with large-scale installation art that blurs the line between event structure and architecture. His education was during a time of revolution in the arts that reflected a general social upheaval, a permissive and liberal period when people actively sought new experiences.

Agis's early work was in collaboration with artist Peter Jones and influenced by Constructivist and De Stijl art, both of which had corresponding architectural movements. Artists like Malevich and Mondrian explored the abstract juxtaposition of colour and form in ways which directly interpreted space, though it was often represented on a two-dimensional surface. Their work was also easily transferable into true three-dimensional form through

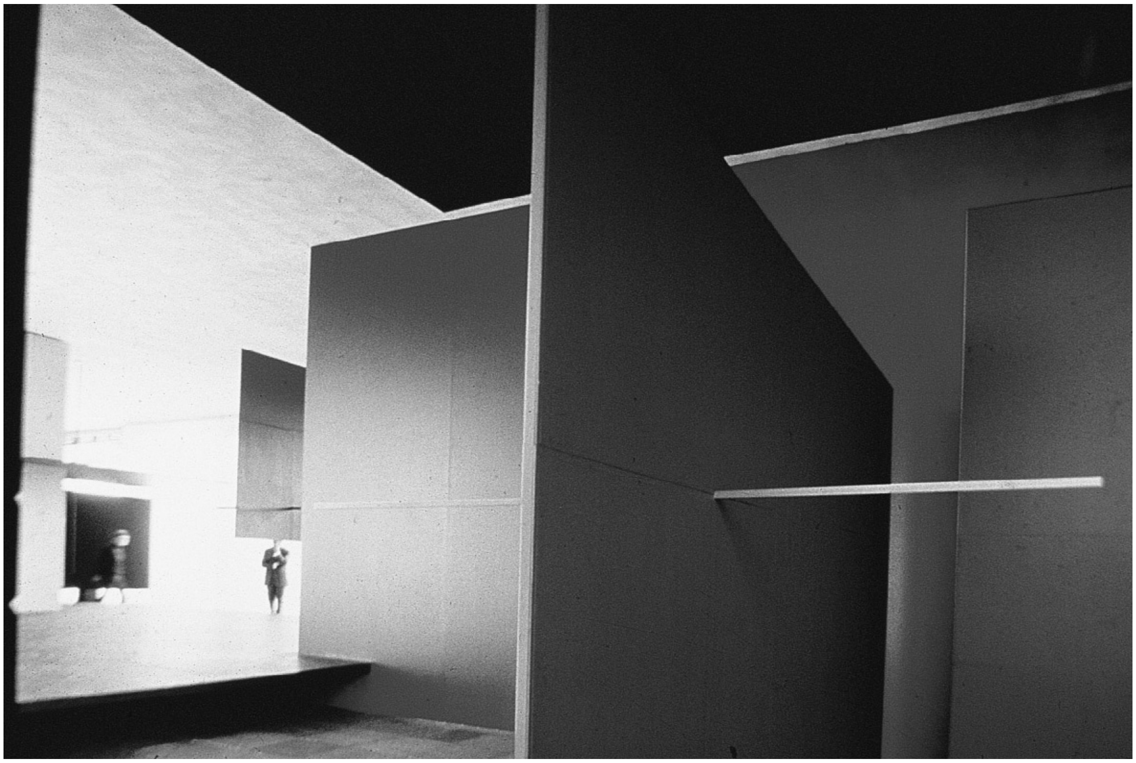

Fig. 14.1 Spaceplace, Maurice Agis and Peter Jones, 1967. This installation took place at the Stedlijk Museum, Amsterdam.

sculpture and architecture. Influenced by the De Stijl environment, Agis and Jones arranged planes, surfaces and line elements to create Spaceplace, an installation that explored the relationship between simple rectangular forms in order to create abstract non-functional spaces that were, however, related to the human body. The work was an attempt by the artists to provide a foil to the chaotic spaces of everyday human activity, which would be more 'defined' and would stimulate human sensory activity in a positive way. The most important manifestations of Spaceplace were at the Oxford Museum of Modern Art in 1966 and at the Stedlijk Museum in Amsterdam in 1967 (Fig. 14.1). The artists created 'active' spaces constructed from aluminium bars and rods, and Lamithane panels that were contained within a blacked-out space lit from behind a translucent screen. The physical elements were arranged within the space in an asymmetrical yet clearly ordered manner that required people to slowly move around within the installation, forcing them to examine their environment with greater care. These installations were temporary and could be moved from place to place by simply dismantling the components and reassembling them elsewhere. The aim of Spaceplace was to create a new environment based on aesthetically controlled considerations rather than conventional functional issues, and the installation therefore relied totally on the provision of a separate shelter environment in the form of a gallery space. Agis felt that this restriction compromised the intensity of the interactive relationship he was trying to achieve between the art work and the public. He therefore decided that in future work he must retreat from the conventional gallery-based arts system into a more public environment that would be perceived as separate from the conventional voyeuristic arts process.

Colourspace

In the 1970s Agis taught sculpture at Goldsmith's College, London, and began to develop, as an individual and in cooperation with his students, new concepts for installation work. Rather than creating objects in space, he wished to utilise objects to create new space. Agis was aware of the

Fig. 14.2 Colourspace, Maurice Agis, 1974. This early version uses multi-coloured volumes of different shapes encircled by a neutral grey tube.

work done by Archigram (which he describes as 'paper work') and other artists like Graham Stevens and Jeff Shaw who were making sculpture from non-traditional materials like plastic. The idea of exploring inflatables as a way to create spaces began initially with the search for new ways to introduce colour in his installations, but it also resulted from the desire to find a cheap, mobile, non-precious medium that could be shaped and modified easily with relatively small investment in time and money. The aesthetic of the plastic itself became more important as experimentation continued and he began to appreciate and control its translucent and flexible qualities.

The first *Colourspace* prototypes were developed between 1970 and 1972 with sponsorship from the British Arts Council and erected for the first time in the London park, Kensington Gardens. The structure consisted of a series of different shaped inflatable spaces, each one a distinctive primary colour. The shapes were linked by tunnels and surrounded by a perimeter circular tube. The structure was made from PVC and inflated by a series of commercial electric blowers. The separate spaces used glued joints for strength, though assembly on site was made with taped joints. Between 1972 and 1982, the first manifestations of *Colourspace* travelled to more than thirty towns and cities around the UK (Fig. 14.2).

Colourspace has passed through many different versions and when the installation has been remanufactured, Agis has taken the opportunity to change and develop the concept. In 1985 the Berlin Senate of Cultural Affairs commissioned Agis to create a more ambitious *Colourspace* for the Berlin Festival. This piece consisted of sixty-four modular cells of different colours arranged in an organic yet defined pattern. The modular system provided several advantages. Manufacture became more easy as a set of repetitive patterns could be used. Erection also became a more simple process as the spaces could be laid out in smaller, more easily handled units. Perhaps more importantly, colour could be manipulated more effectively by corresponding cells of different colour next to each other to create polychromatic effects. The use of the cellular system meant that these combinations could be varied with each installation so that experimentation with colour patterns could take place. This structure toured to many cities in Germany throughout 1986 and 1987.

Six variations of *Colourspace* have been made between 1985 and 1992 though Agis has also constantly changed the arrangement of the structure from site to site, experimenting with form and colour (Fig. 14.3). The latest and last *Colourspace* was made initially for the North Sea Festival at Stavanger in Norway in 1992. Building on the

Fig. 14.3 Colourspace at Derby, 1991. Though based on the same principles, this is a different version of the installation which also has a tension structure to identify the entrance.

experience of the previous project the new version consisted of sixty-eight identical ovoid cells, each measuring 3 metres square on plan and 3.5 metres high. There are twelve units each of blue, green, red and yellow colours and twenty grey ones. Agis states that the grey units are used in much the same way that an artist uses a palette when mixing his colours – to provide a subdued tonal area that enhances the dramatic effect of pure colours. Colours can therefore either be seen separated from each other by the grey areas, or in more complex combinations when light reflections synthesise to form remarkable colour patterns. The entire structure covers an area of 900 square metres when inflated. This *Colourspace* also uses PVC sheet a third of a millimetre thick with a combination of studio-made glued joints and taped joints made on site. For the first time Agis began to combine his colour and environmental effects with music, and commissioned contemporary composer Stephen Montague to create a sound-based piece that would enhance the visitor's experience. The final *Colourspace* travelled for three years from 1992 to 1995 throughout Europe to Norway, Denmark, Germany, Spain and the United Kingdom. Previous versions were erected in Los Angeles at the International Art Fair and in Brisbane, Australia at the 1988 World Expo.

Agis receives his commissions from clients and sponsors based on the interest that his previous work has generated. Those who have not actually experienced the environments he creates are surprised by the unique qualities of the space as it is not adequately conveyed in photographs. He is often asked to bring *Colourspace* back to the same venue again. Clients are totally unaware of the

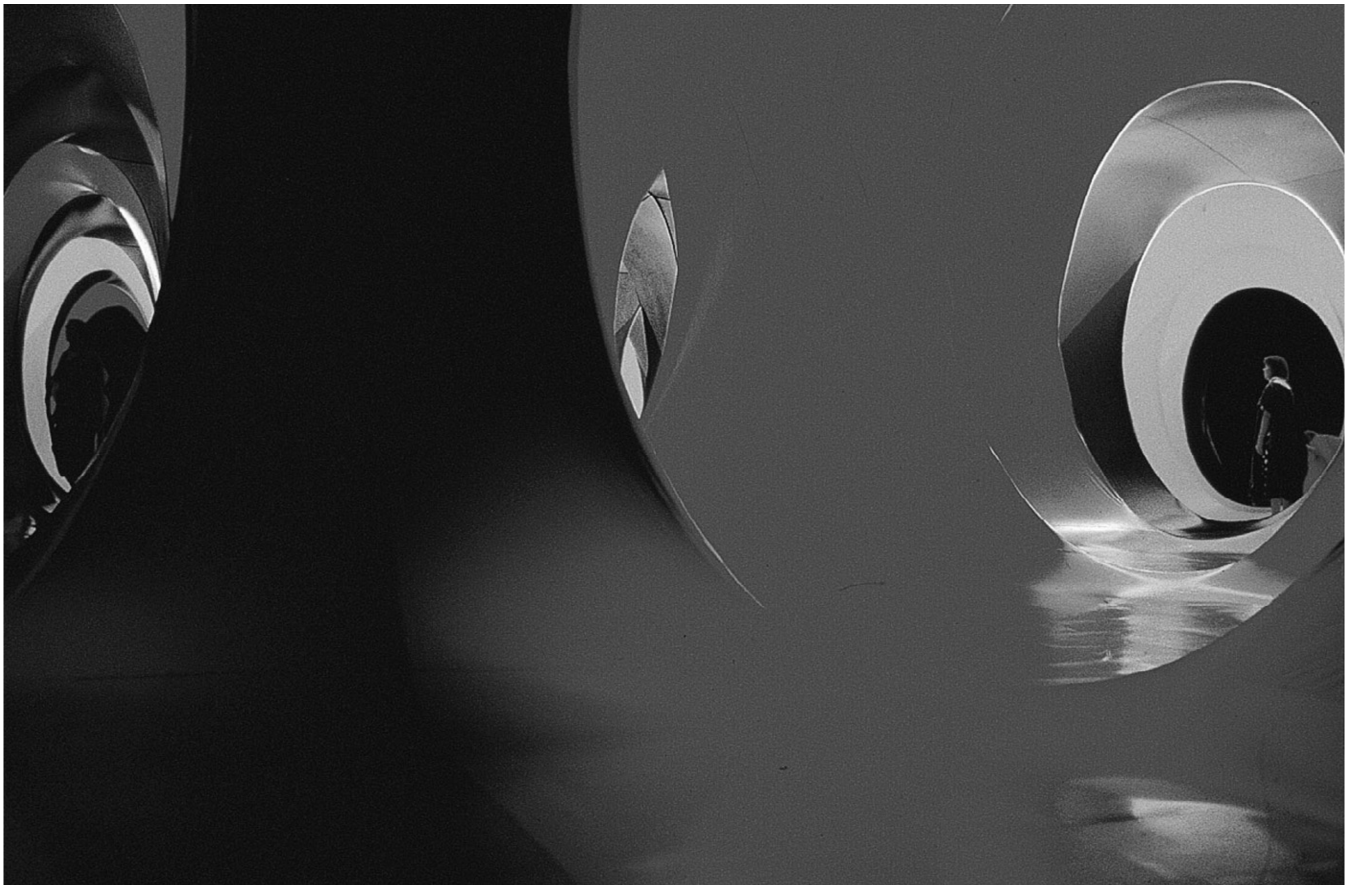

Fig. 14.4 Colourspace interior.

technical issues that surround the creation of such a structure and their response to the installation proposal differs depending on their own experience. Commissioning bodies range from government sponsored festival organisers to commercial groups and arts funding teams. Whoever the client is, Agis develops his personal ambitions for the project without their involvement, though collaboration with other arts-based disciplines such as music, dance and performance have been utilised in the development of activities within the environment.

Agis is always involved in site selection and makes all efforts to control the structure's deployment location and position himself. He visits all sites prior to erection and prefers urban city centre sites in order to reach the maximum number of people. Bureaucratic restrictions on its deployment vary from place to place, however, most authorities perceive the structure as a building rather than an art installation and put means of escape and other safety issues high on the agenda. Agis deals with all aspects of contract, legal requirements, insurances and licences which are as much a part of public art projects as they are of the building process. Though the greatest capital cost is in manufacture there are also running costs associated with deployment – maintaining the installation, special site preparation and controlling the public's access and behaviour. A charge is always made for entry. Agis regards this as important as it means that no matter who has commissioned the manufacture of the structure, the public ultimately become the main sponsors.

Colourspace can normally be erected within twenty-four hours though it may take much less time (three to four hours) with an adequate number of helpers and an experienced crew. No component is made heavier than two people can carry with ease. The entire structure is transported in deflated form on a flat-bed truck or in a van. The cells are laid out in deflated form on the ground, sometimes varying the pattern to create new effects. They are jointed to each other with tape using the permanent glued joints as guides to line up connection points. When all joints are made, commercial electric blowers are connected through ducts made from the same PVC material and switched on. The structure then expands and stiffens which is a performance in its own right. The structure is usually tethered at the perimeter using ground anchors on soft sites and weights on hard sites. Rough surface sites must have a covering of sand to protect the PVC skin. Once set in position *Colourspace* is allowed to deflate when not in use and reerected by simply starting up the blowers. It can be deployed without trained operatives though there must be at least one experienced supervisor present. A new erection team can be trained very quickly.

To experience *Colourspace* you remove your shoes (to avoid damage to the membrane) and wear a coloured cape that merges your figure with the fabric but also makes other people moving about inside the structure part of the colour pattern (see Plate 10). You enter through a 2-metre high vertical slit into a grey cell and from there can immediately see a series of avenues that radiate from the entrance space. Moving through these avenues, colours change around you and envelop your own figure so that your cape and skin takes on the appearance of the space in which you stand. At each intersection more avenues radiate away with seemingly infinite varieties of colour. Never has the experience of colour been so intense as in *Colourspace*, an intensity that appears to saturate the air. Because your sensory perceptions have been altered, to emerge back into the real world is to become part of a seemingly much greyer environment than the one you left just a few minutes before. Many people find this experience profoundly affects their senses and feelings, often in a deeply emotional way. Agis keeps a journal of visitors' comments which shows repeated remarks on the existential feelings they have felt. The intensity of colour which many artists have used throughout history to create emotion in the spectator is clearly reinforced in this environment. In *Colourspace* the viewer has become a participant, immersed in colour and a unique, soft-skinned organic space (Fig. 14.4).

It is possible that the dramatic emotional effect that *Colourspace* has on people may have quantifiable physical benefits, and Agis has had enquiries from hospitals and schools about the provision of smaller versions for therapeutic and educational use. He does not believe that *Colourspace* is a precious art form that can only take place under the strict control of the artist and is considering the manufacture of a commercial version that could be erected by its users. The modular construction strategy and ease of deployment makes this feasible. He has also been asked to make spaces for specific functional situations, a restaurant space in America and more recently and more likely to be realised, *Airspace*, a mobile performance space for contemporary classical musicians initiated by Nick Pendleberry of the Smith Quartet. The objective is to create a transportable space that will house performances of experimental music, dance and voices that would be combined with visual effects.

Dreamspace

The ideas for *Dreamspace* began to emerge in 1985 and have been developing in parallel with the operational *Colourspace* since then. Agis comments that the main limitation has been finding the capital to complete this more ambitious project. *Dreamspace* will not only utilise a larger number cells, but also for the first time since the 1970s, different shaped spaces, though the modular concept will remain (Figs 14.5, 14.6).

Dreamspace I was made in 1996 and incorporates four 5-metre high spaces within its eighty-eight cells. The 1600 square metre structure is inflated by eight centrifugal blowers. One of the reasons for the different shaped cell structures is to increase the capacity for dance and other performances. As well as the natural light effects and musical experience devised in *Colourspace*, the new structure utilises artificial lights positioned outside the space within the vertical 'columns' formed at the interstices of the ovoid cells. These are synchronised with music and sounds and dancers inside the space. The use of artificial lights further extended the colour effects that are possible but also enabled the experience to become operational at night as well as in the day. A sixteen-speaker electronic sound system is set out in the 'column' spaces which broadcasts music throughout the structure.

The manufacture of *Colourspace* was carried out by Agis himself in his London studio using

Fig. 14.5 Dreamspace in Denmark, 1996.

simple patterns and glued joints. The increased size of *Dreamspace* means that both the means of manufacture and deployment have had to be developed. PVC membrane has been used for both projects; however, up until 1980 *Colourspace* was made with locally sourced material. For *Dreamspace I* Agis went direct to Taiwan where 80 per cent of this material is now made, ironically using British-made tools bought from British companies that folded under pressure from their parent companies whose main business was in other areas. Agis can purchase the same material in Taiwan for a third of the UK cost and by patterning, cutting and making up the main components there, save further costs in transportation. The entire structure of *Dreamspace I* is made up of twelve main cell groups which can be arranged in different patterns. By grouping the cells, erection time is reduced and site joints are kept to a minimum. Factory-made joints are now welded for strength and a better finish. Agis has now incorporated commercially made PVC zipper joints, a more complex alternative to site joints that are easier and more convenient to operate than taped joints. Agis has also introduced a tension membrane structure to identify the entrance area.

In April 2002, Maurice Agis premièred Dreamspace IV in Castellón, Spain. The component parts were once again made in Taiwan and shipped to Agis' workshop where they were assembled into the complete structure. This involved joining together the sixteen separate units and fitting the entrance and air inlets. The entire structure was transported to site in two crates, which were carried together on a small lorry as the total weight was less than 2.5 tonnes. One crate contained blowers, music amplifiers, holding down ropes and fixing pegs and the other contained the entire Dreamspace structure in one piece. In Castellón, thirty students (and some of the staff including the director, Alain Campos) from the School of Art assisted in laying out and erecting the installation. Agis is now making plans for a further evolution of Dreamspace which will cover an area of 3600 square metres. As well as music, dance performance and lighting, he also hopes to incorporate water into the installation by setting it into an artificially created pool fed by fountains and spray jets.

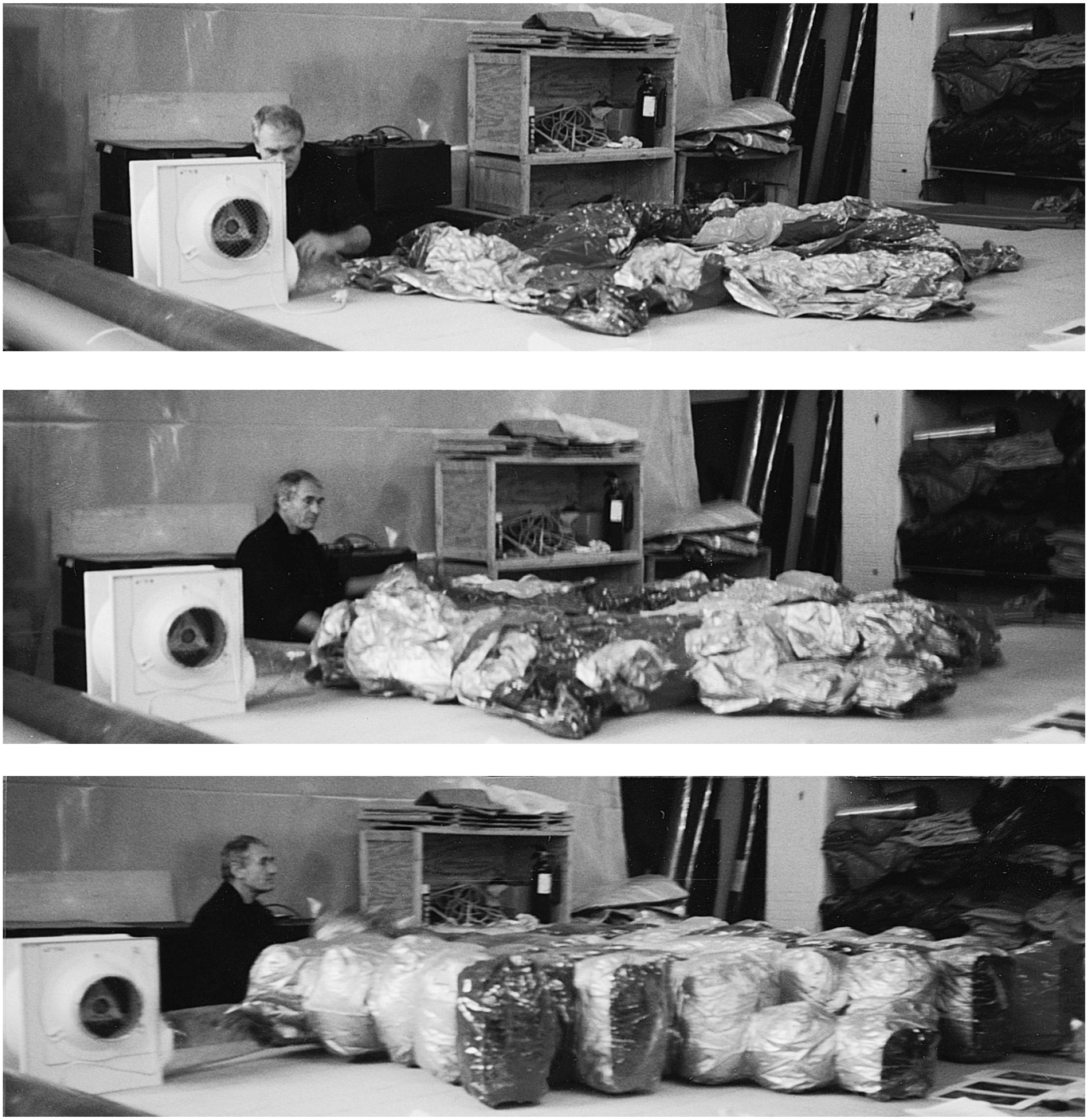

Fig. 14.6 Dreamspace model, Maurice Agis, 1995. Made from the same materials and inflated in the same manner, the model is an effective design tool but is also valuable in explaining the qualities of the installation to sponsors

Maurice Agis believes that *Colourspace* and *Dreamspace* form a contemporary response to the exploration of the aesthetics of colour and space. Because people enter completely into the environment, they take a part in the artistic process and it therefore has much greater immediacy for them. This heightens their understanding of the artist's ambition but also creates a personal experience unique to each individual. The fact that these environments are transportable is integral with this

Fig. 14.7 Maurice Agis, Dreamspace IV arrives on site offloaded from a container.

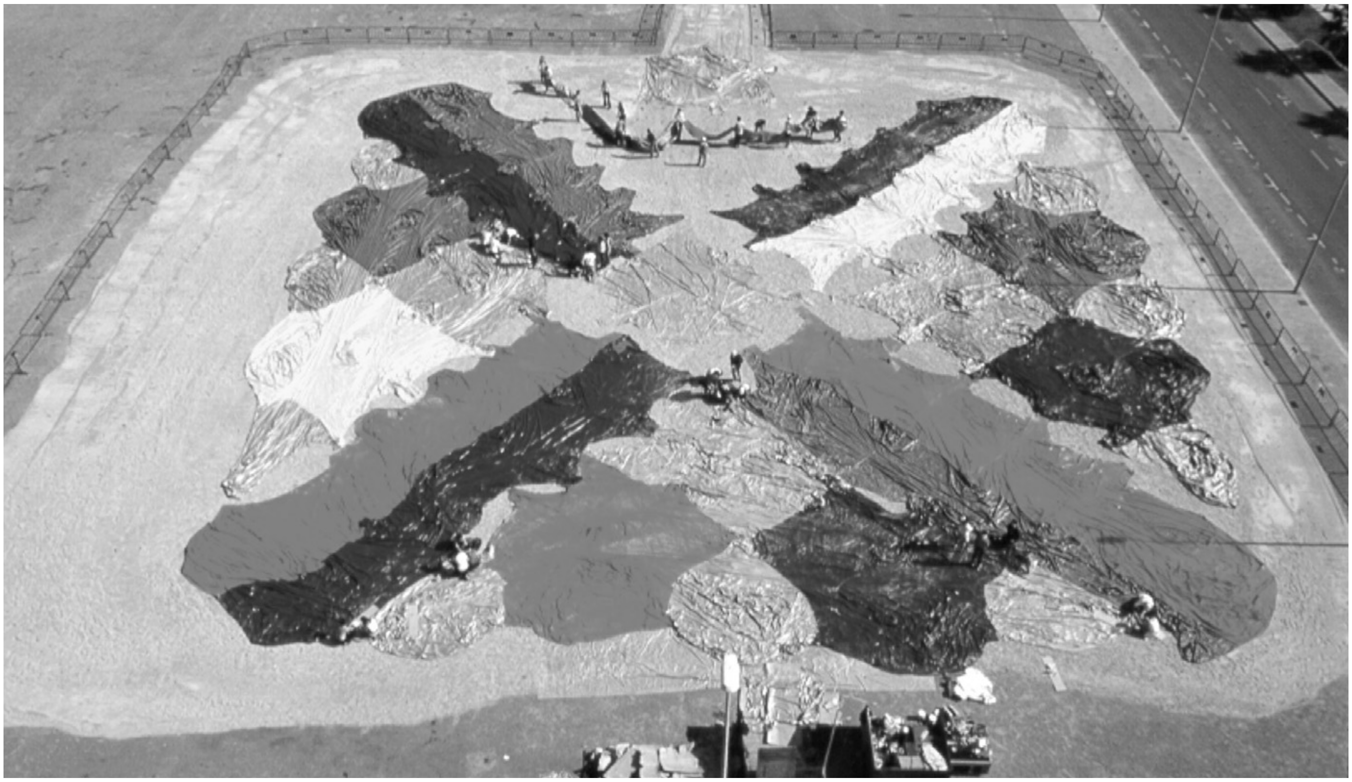

Fig. 14.8 Dreamspace IV being laid out prior to inflation.

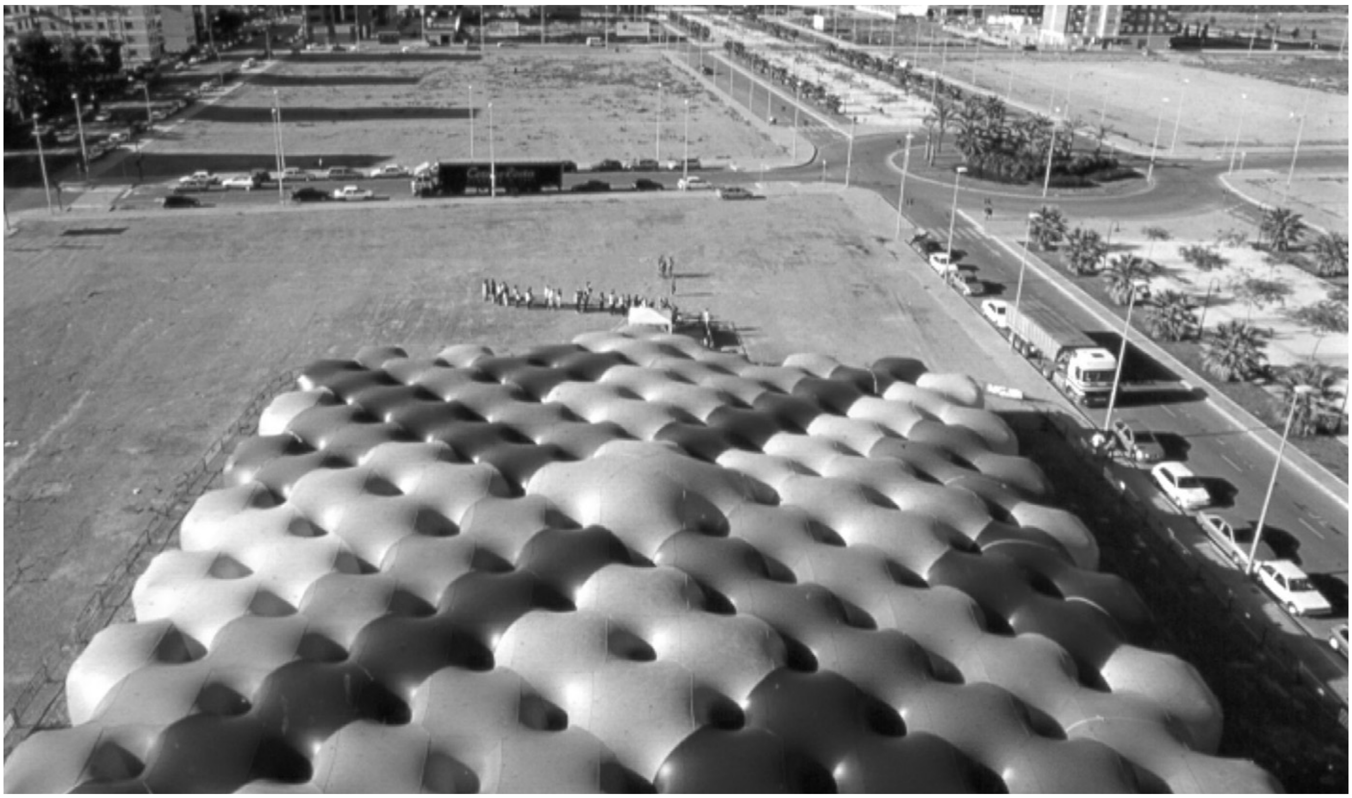

Fig. 14.9 Dreamspace IV on the edge of the city, Castellón, Spain.

Fig. 14.10 Dreamspace IV interior.

ambition. To bring the art to the people and take it out of a conventional gallery space breaks down formal barriers and introduces the work to many people who normally have no interest in art or reject it as an elitist phenomenon. Agis also believes that his work has particular relevance in our perception of the urban environment. He states that this sort of temporary structure can populate public spaces with a 'building' type structure which does not, however, represent any particular governing authority or commercial power base and is therefore both revolutionary and free. An event generated in a public space in which the city's inhabitants can become directly involved defuses, if only temporarily, the authority of the established system. He states that people 'recolonise' that part of the city for the duration of the event. The easy erection and transportability of the structure is an essential feature that makes it possible for it to appear anywhere and also makes clear that it is distinct from the conventional art authorities that generally control gallery and museum space.

Agis has created a manufactured, transportable, easily deployable structure that creates a unique controlled environment. Its purpose differs from most architecture in that it is completely dedicated to creating highly personal, sensual, physical and emotional responses from its occupants, yet its scale and form mean that it can undoubtedly be examined in architectural terms. The transportable form has been adopted by its designer for reasons which are common to many portable buildings with more functional purposes. In seeking the purest and most direct form of artistic expression Agis has found that the transportable environment provides not only the greatest freedom, but also the most potent medium.

Further reading

Green, Trevor; Jones, Peter, and Agis, Maurice. Spaceplace, catalogue for exhibition held at the Museum of Modern Art, Oxford, 28 November to 24 December 1966.

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Inflatable Lunar Habitat

Date: **1987–1995**
Client: **Planetary Surface Systems Office, NASA, Houston, USA**
Architect: **Advanced Programs Office, NASA**
Lead designer: Kriss Kennedy
Engineer: **Advanced Programs Office, NASA**
Consultants: Industrial design: **John Frassanito and Associates**
Inflatable materials and structures: **ILC Dover**

ISS TransHAB

Date: **1997–2004**
Client: **Exploration Office/Advanced Development Office, NASA, Johnson Space Center (JSC), Houston, USA**
Architect: **Advanced Programs Office, NASA**
Lead designer: Kriss Kennedy
Engineer: **Advanced Programs Office, NASA, JSC, Structures and Mechanics Division:** Dr William Schneider, Horacio de la Fuente, Gregg Edeen, Jasen Raboin
Consultants: **ILC Dover**
Contractor: **Advanced Programs Office, NASA, JSC**

Though the extreme environments of the Arctic and Antarctic have been used as models for extra-terrestrial situations, and there are parallells between vehicles designed for space travel and the bottom of the oceans, conditions in space are more extreme than anywhere found on the surface of this planet. It may therefore appear that the inclusion in this study of a detailed building proposal for another planet may have little relevance to our understanding of terrestrial portable architecture; however, the logistical problems of building in space have many parallells with Earth-bound temporary building design. Virtually all the components for the construction and transportation of extra-terrestrial buildings must be manufactured using technology which has its basis in previous experience on Earth. These pre-manufactured sub-assemblies must then be transported many thousands of miles to their deployment location. There are also great limitations on their weight and bulk because of the payload problems associated with lifting any object free of the Earth's gravity, and they must therefore not only be able to resist the harshest environment yet encountered, but also be as lightweight and compact in transportation as possible. Despite the remoteness and unusual nature of their site and the unique operations associated with their special purpose, space exploration shelters will still have to support the many pragmatic human activities that are required for a similar expedition on Earth. The design of portable buildings for earth and extra-terrestrial use therefore has many similarities in that it relates to directly comparable functions, materials technology, manufacturing techniques, transportation and deployment strategies.

Not all extra-terrestrial architecture can, however, be described as portable. Construction and servicing facilities associated with the Lunar and Mars habitation programme, like the space stations that have now been in use for generations, are portable in one sense in that they are constantly moving in orbit around the Earth. However, vehicles move to and from them, rather than vice versa. The logistical arrangements for habitation of other planets depends on structures which are essentially permanent, though their deployment strategy is based almost totally on prefabricated components, transported from their place of manufacture and designed for easy and efficient on-site assembly. These buildings are therefore portable only in the sense that they are remotely manufactured. However, the detailed design and logistical arrangements they utilise are undoubtedly of interest because of their innovative approach to the solution of difficult problems. These solutions may be transferable to terrestrial buildings with similar, though less extreme, constructional issues.

Building in space

The Space Exploration Initiative (SEI) instigated by President Bush in 1989 heralded a renewed interest in the establishment of viable platforms on which human beings could live and work in space and our neighbouring planets. The Russian Space Station Mir continues to be occupied for long periods by cosmonauts and recent missions by the US Space Shuttle have concentrated on adding new docking devices for the connection of new facilities and easy access by a variety of space vehicles. Another initiative is the International Space Station which is to utilise the collaborative technology and resources of many nations. The next stage in space exploration depends largely on the appropriation of sufficient budgets from governments and international space exploration organisations which have become conscious that such substantial funds must be underwritten by the future economic benefits gained from commercial activities in space. Much detailed work has already been carried out in this field involving detailed design, prototype manufacture, and concept proving that has enabled those involved to discuss confidently issues related to 'when' we occupy other planets rather than 'if'. Several separate organisations have been exploring a diverse range of techniques for the establishment of sustainable shelters, primarily on Mars or the Moon. The Lunar programme is the most advanced, not least because the Moon is Earth's nearest neighbour and therefore accessible in a relatively short travel time of about three days. Since humans have walked upon its surface it is also the planet about which we know most and it has therefore been possible to determine the tasks that would take place on the planet's surface and select possible habitation sites.

The first visit to the Moon by human beings took place in July 1969 and was a dramatic event in human history that signified the important impact of technology on everyday life. However, since that event the social relevance of space exploration has appeared to diminish and any return to the Moon, this time to stay, must be based on scientific and commercial reasons that result in a quantifiable return on investment. These may be found in the unique qualities of the lunar environment – a low gravity and lack of atmosphere which allows for laboratory conditions attainable only with great difficulty on Earth. The geology of the Moon is also of great interest to scientists in that it may provide a source of information about the make-up of the Universe, and the possibility that it could be exploited for rare and precious minerals and metals. Lunar ore processing plants are one of the many hypothetical scenarios that provide encouragement for off-world exploration.

The Lunar habitation strategy described here deals not only with constructional issues but also with the psychological impact on the inhabitants of such a remote outpost and the urban planning of a base that will be required to respond to planned growth over several decades, both of which are also concerns in terrestrial architectural projects.

This project has been developed primarily by space architect Kriss Kennedy, a graduate of the University of Houston, Sasakawa International Center for Space Architecture (SICSA), USA. SICSA runs an internationally recognised course in space architecture led by Larry Bell and Guillermo Trotti (who have also designed off-world construction strategies) developed under the sponsorship of Japanese philanthropist Ryoich Sasakawa. Before studying at SICSA, Kennedy who is a licensed practising architect, had a conventional early architectural education, balancing college studies with several years in architectural practice. A period of co-operative training at the NASA Johnson Space Centre in Houston led to the offer of a permanent post. SICSA has since trained other architects for work at NASA and other aerospace companies.

The Lunar Base systems study was first commissioned by NASA in 1987. The first proposals for a lunar habitat were based on the assembly of rigid modules similar to those used in existing space stations. These were very limited in size due to launch payload and vehicle design constraints and therefore lighter, more compact alternatives were investigated. In the early days of design, budget was not an issue – safety and performance and confidence that the objectives could be achieved were paramount. However, the fact that the inflatable concept could be lifted into orbit using existing vehicles and systems rather than waiting for the development of a heavy lift transport vehicle, had clear practical and economic benefits. The design work is coordinated within an in-house team led by Kennedy that also includes mechanical, electrical and structural engineers and reports back to the Planetary Surface Systems Office, a branch of the NASA Explorations Programs Office. Specialist outside consultants such as ILC Dover were used to advise on the inflatable structure material and design and industrial designers John Frassanito and Associates advised on the construction and assembly procedure. This design team organisation is very similar to that often used on conventional building projects.

Parallel with NASA's in-house work, several other aerospace companies have begun to undertake similar design projects in the hope of obtaining NASA funding to develop their concepts. Conventional building contract organisations have been used as project consultants and design critics

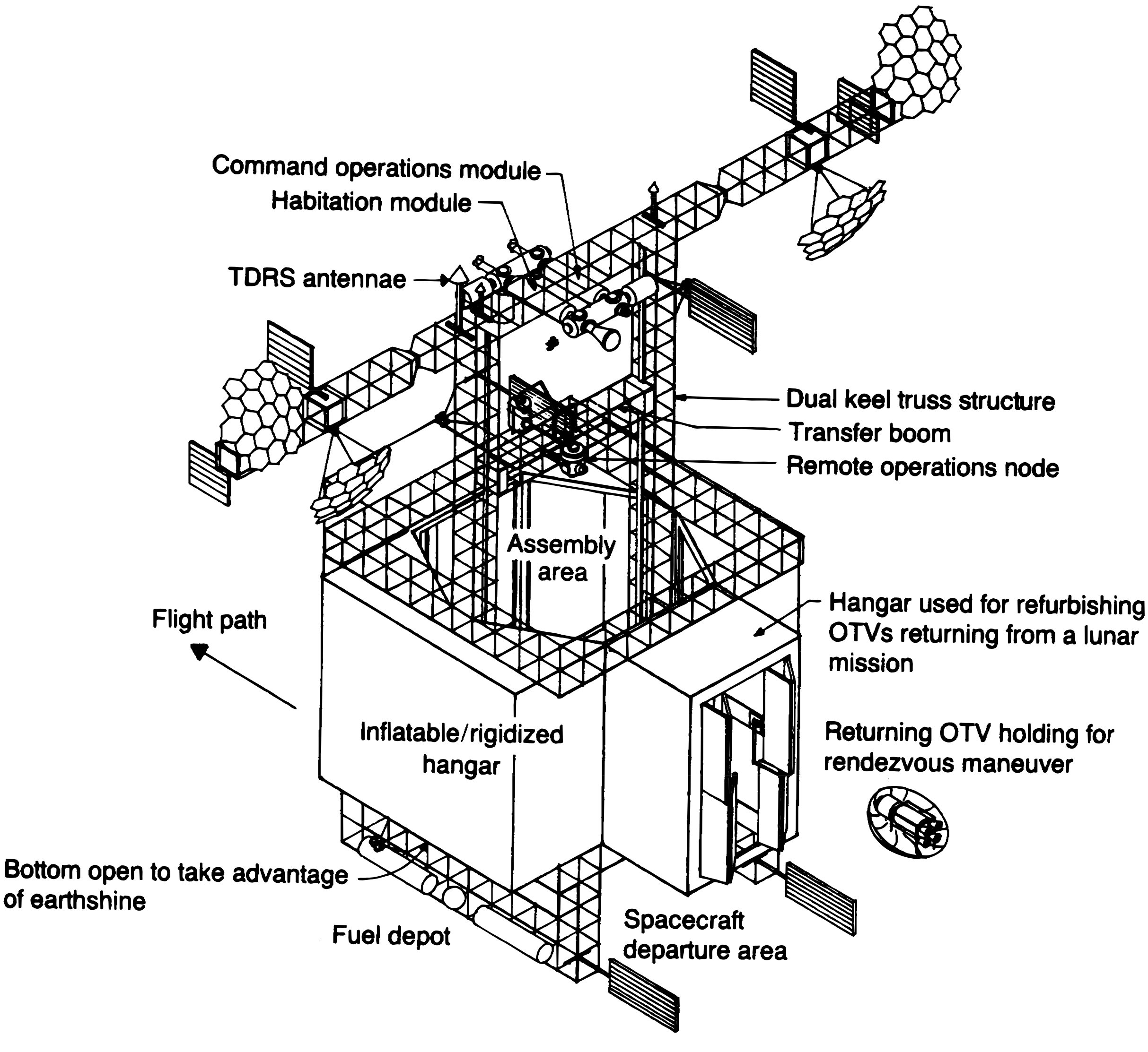


Fig. 15.1 NASA Transportation Node (TN), 1989. This 'atrium'-based design is one of several possible configurations that have been considered. It is planned in a similar way to a group of terrestrial buildings with maintenance and storage functions.

to gain insight into constructional issues that are similar to those on Earth, and ensure that relevant technological advances in the construction industry are applied where appropriate. Though the project described here has passed through several stages, design and development work still continues on shelter habitats.

Many of the tasks associated with a lunar settlement have parallels with the establishment of a remote base on Earth. The first task to be under-

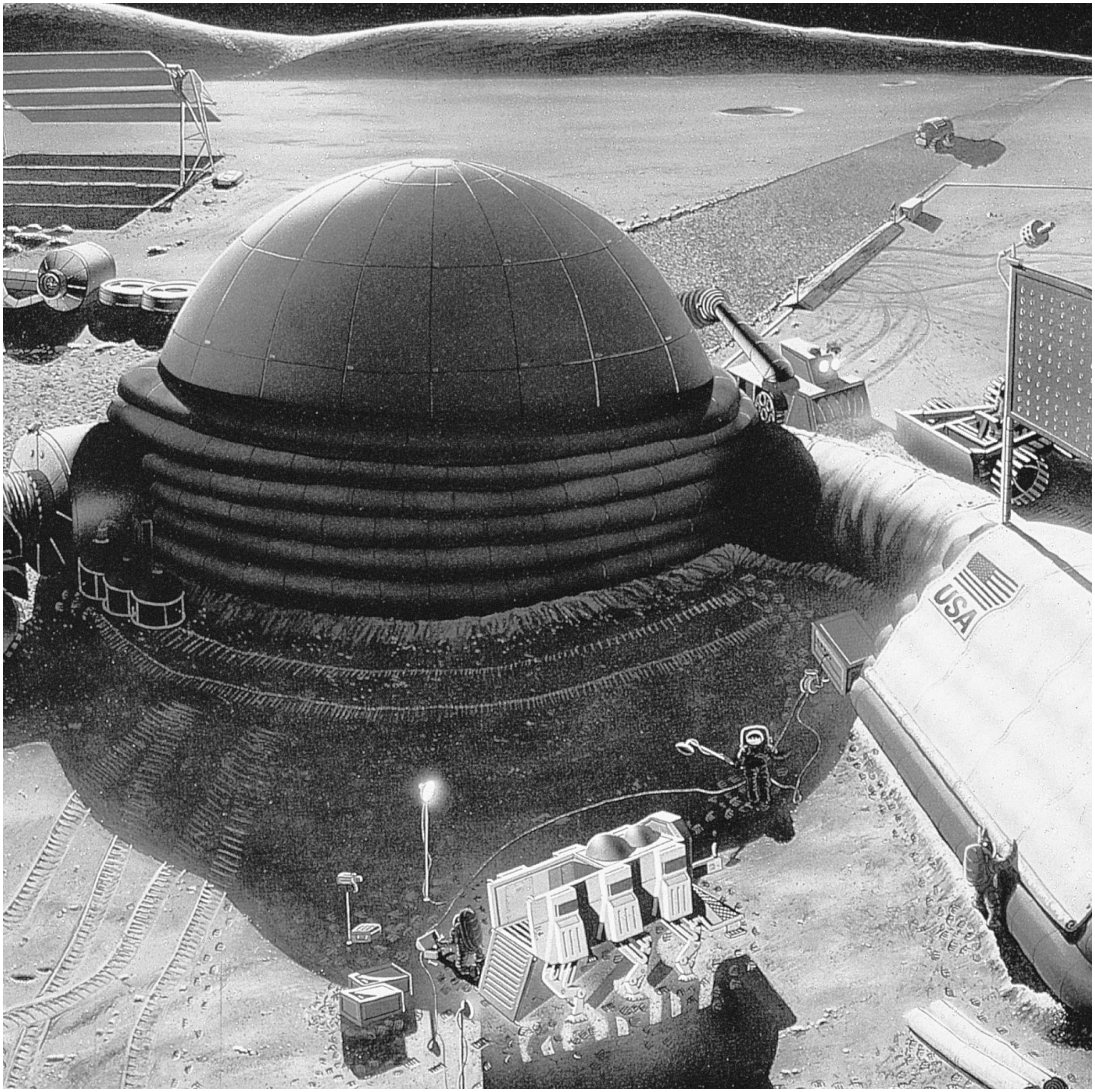


Fig. 15.2 NASA Lunar Outpost project, 1989. This early version of the inflatable habitat concept shows all the major components of a lunar base. At the centre is a spherical inflatable habitat built into the lunar surface and surrounded by a continuous bag of lunar regolith. To the top right is the graded road to the landing pad and top left is a solar power plant and oxygen production facility. Bottom right is a construction shack with thermal radiator on top.

taken is to decide on the landing site and then identify topographical and geographical data – a complex task for the Moon because of its relative inaccessibility. Fortunately, much of this data has already been collected by remote observations from Earth and previous surface and orbital missions. New dedicated missions might utilise robotic probes that could supply information via telecommunications, or by gathering and returning samples. Further manned missions might also be necessary to determine especially crucial factors, for instance the presence of water in the form of ice at the Moon's south pole. A find such as this would have dramatic effects on the design of a long-term lunar mission, greatly reducing the payload on the constant servicing trips from Earth that a permanent base would require.

Though the basic system for transporting components, cargo and propellant from Earth to Earth orbit exists in the form of the Space Shuttle, special cargo vehicles might also be developed to make this task more efficient. A new multi-purpose communication spacecraft to travel between Earth and the Moon would also be required. This vehicle would be constructed and serviced in space and would never need to land on Earth. This strategy therefore necessitates a permanent space habitat called a Transportation Node (TN) which would be established in orbit remote from other space stations in order that its presence, and the traffic it would generate, would not disturb the micro-gravity required for delicate experiments (Fig. 15.1). The TN proposals developed by NASA utilise modular systems to build up a series of alternative approaches to the organisation of an orbiting service station. The TN configuration can be altered in response to the nature and scope of the task the facility is asked to accommodate – the mission frequency, type and size of payloads to be delivered, even the type of vehicle that it is to service. All concepts describe, what are in effect, buildings in space. Perhaps the most interesting is the 'Atrium' TN. This building is based on a T-shaped triangulated box-frame main structure. Along the bar of the T are attached highly serviced pressurised habitation modules for the six permanent and seven temporary crew members – command operations, logistics, and health maintenance facility modules together with antennas and solar panels. The twin vertical bars frame a large cubic structure to which is attached non-pressurised storage hangars. Two hangars can contain up to two Orbital Transfer Vehicles (OTV) each; two more are used for maintaining and servicing the Lunar ascent/descent vehicles. The OTV may sometimes carry either crew or cargo, transported in separate dedicated modules attached as required to the main vehicle. The fifth hangar would hold these modules, and the sixth would be used for vehicle servicing. These enclosed spaces would provide protection from micro-meteroids and orbital debris. The central atrium space is an assembly area where the different components of a mission are brought together from their various dedicated hangars and fuelled up in a departure area at the open end of the cube before departing on their journey. A transfer boom with a pressurised pod would convey the crew to the departing spacecraft. This facility could be assembled in space using components manufactured and then lifted from Earth. Its dry weight is estimated at 320 metric tonnes with a further 182 metric tonnes of propellant. The hangars enclose a total of 88,000 cubic metres of space. The utilisation of a modular system would simplify assembly procedures and ensure flexibility for future expansion and configuration changes. All the constructional principles and special systems described here have already been developed and have proven their worth in previous missions. It is simply the scale of the project that has so far prevented its realisation.

Habitat Facilities

In the same way that a terrestrial building cannot be erected without support facilities for building personnel, administration, storage of materials and specialist workshops, a lunar habitation module requires support structures that are available instantly on arrival at the building site. These must provide safe shelter for humans and machines whilst the main facilities are being erected (Fig. 15.3). In a dangerous airless environment it is also important to keep external operations to a minimum. This significantly affects construction logistics in that all procedures need to be carefully rehearsed before the mission. Once on site, sub-assembly should be carried out in safe environments as far as possible.

As the facilities are in such a remote place other non-habitation structures are required which are, however, just as important for the operation of the base and the safety of the personnel as the habitation module. A permanent base will therefore consist of a range of integrated facilities that would include a landing site, oxygen-manufacturing facility and power plant. The site of the first Lunar base might simply be a flat area free of obstacles,

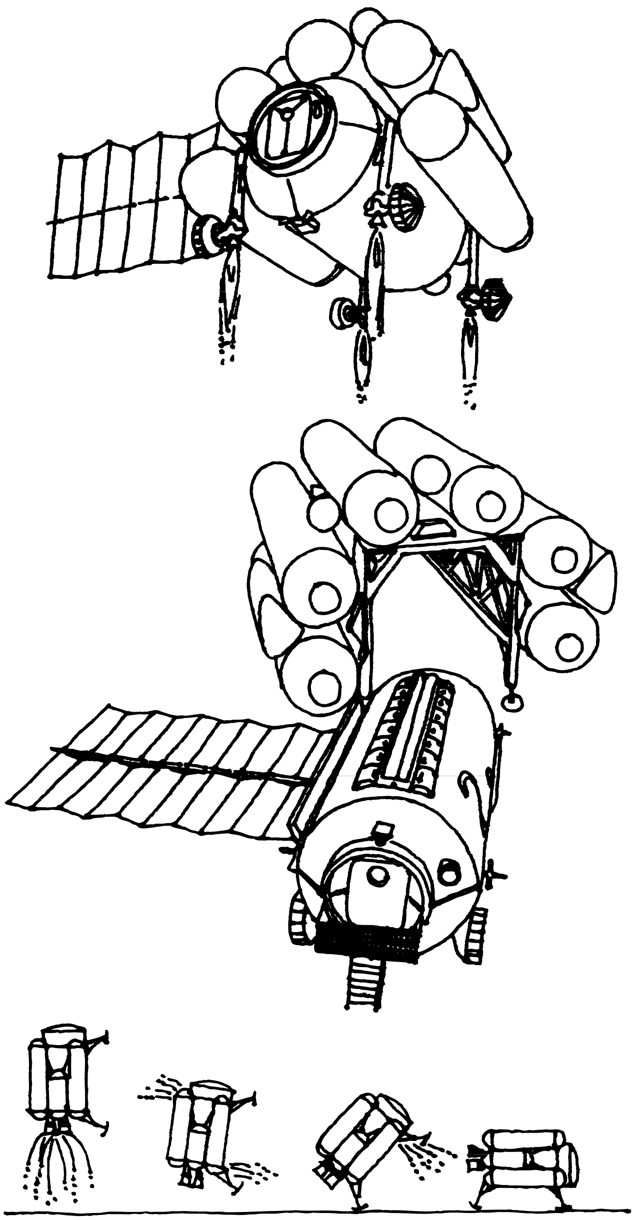


Fig. 15.3 NASA Lunar Outpost Rotating Lander Concept, 1993. The first habitat will need to be transported as a complete module to provide immediate safe shelter. In this proposal, launch and landing stresses are carried longitudinally through the structure in the most efficient manner. When near the surface the module rotates for touchdown. The habitat can then either be moved free from the transport superstructure or remain in place, with the fuel tanks filled with regolith for radiation shielding.

however, early improvements such as the levelling, grading and sealing of the surface to reduce dust raised during arrival and departure of craft would need to be made and eventually, servicing and refuelling facilities would be required (Fig. 15.2). Power requirements for an early Lunar base would be in the region of 100 kilowatts which would supply the environmental control systems, laboratory experiments and vehicles and equipment used in building, exploration, and working on the lunar surface. A number of different systems suitable for operation on the Moon have been assessed. The simplest consists of a flexible, solar-powered photovoltaic mat that could be unrolled on arrival to lie flat on the surface. As solar power is not available at night the array must provide sufficient energy to charge batteries for night-time use – an area of about 2000 square metres would therefore be required. An alternative is the solar dynamic system which converts heat in the thermodynamic cycle to electricity. Though more efficient than photovoltaic systems, it is also more bulky and complex, obvious problems where ease of transportation and reliable operation are important issues. Fuel storage would be most efficiently carried out in fuel cells which chemically combine oxygen and hydrogen to form water which releases energy, and stores it by converting the water back into its separate components using electrolysis. An important advantage of fuel cells is that they have about a tenth of the weight of batteries.

A longer term proposal might be nuclear energy. This solution provides continuous power during the day and night with little requirement for storage except in the case of an emergency. However, many of the problems of terrestrial nuclear power would also apply on the Moon – shielding from radiation, the impossibility of maintenance once the reactor becomes operational and the eventual redundancy of the power plant as radioactive fission products accumulate in the core. Eventually the power plant would become unapproachable, even when it was shut down.

An oxygen plant would also be required, perhaps initially in the form of a test facility consisting of several small plants of different design, each producing part of the total requirement. Due to the complexity of testing and operating, such diverse systems as these would be largely automatic. Though a number of systems might be tested, the principle would basically be the same, utilising a mining process that would crush the lunar regolith to release small amounts of ilmenite, an oxygen-bearing material which when mixed with hot hydrogen produces water and other oxides. The water can then be split into oxygen and hydrogen, the former stored in liquid form for conversion to gas as required, and the latter recycled back into the process.

Inflatable Lunar Habitat

Because of the many new problems of lunar building, the design team have been forced to find innovative solutions to construction issues. Though the eventual ambition is to provide permanent buildings, the logistical problems associated with the requirement for instant availability of safe, usable shelter means that their proposals have much in common with portable building design. Considering the environmental conditions, the most surprising strategy has been the exploration of the inflatable approach to building provision, though this has now passed successfully through several prototypical and draft design stages. An early precedent for the work was the NASA Langley Research Center Lunar shelter, 'Stay Time Extension Module' designed in conjunction with Goodyear in 1965. Two dedicated prototypes have also been made – a small 2.23-metre diameter sphere made of kevlar sailcloth and a four-storey, 11-metre diameter mock-up structure. Both these prototypes were based on an earlier concept for a spherical building. This experience has resulted in

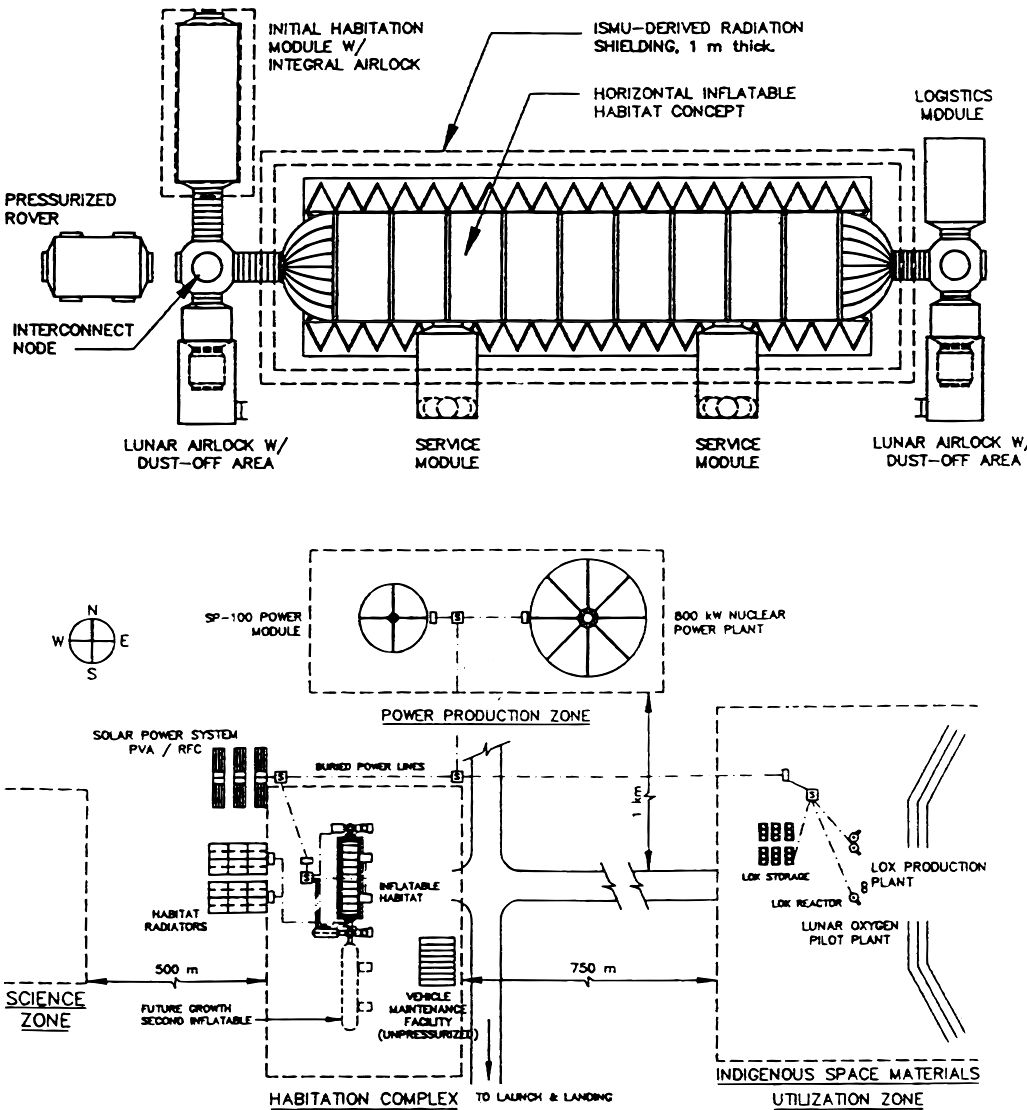


Fig. 15.4 NASA Horizontal Inflatable Habitat, 1992. Top: building layout. The central habitat is constructed in-situ, the other elements are transported as complete modules from Earth. Bottom: site layout.

CASE STUDY 15

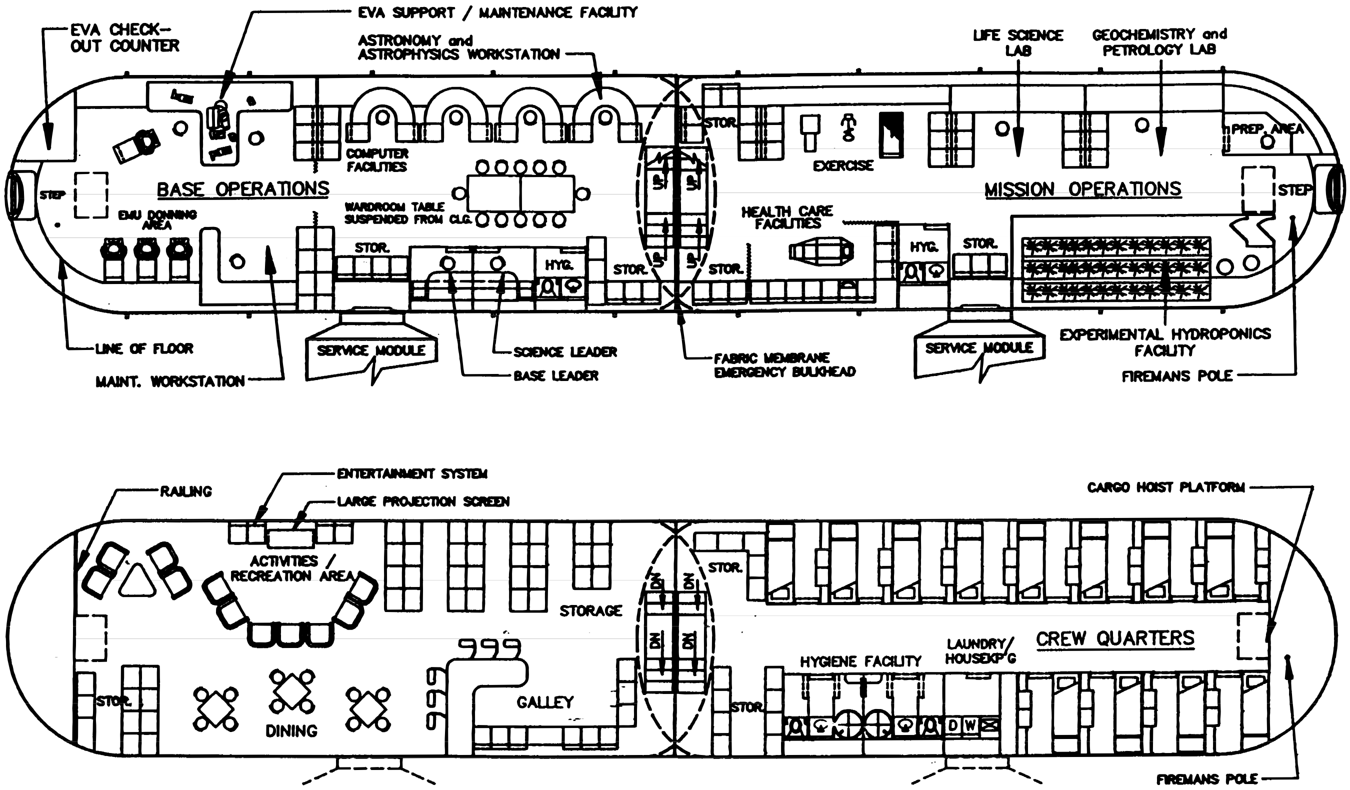


Fig. 15.5 NASA. Floor plans: level 1 (top) contains base and mission operations, level 2 (bottom) contains crew quarters and support facilities.

the current horizontal tube design. The design is at a fairly advanced stage, though for understandable reasons this concept has yet to be proven on site!

As with the TN, a modular approach has been taken in its construction which allows for interchangeability in erection and flexibility in use. The complex consists of a relatively small initial habitat module with a micro-meteorite resistant hard skin, which would be fully operational immediately after deployment. This would provide a safe base for the personnel whilst the main habitat was under construction (Fig. 15.4). The air locks, complete with dust-off facilities, would also need to be installed at the beginning to allow easy access to the external environment. Self-contained service modules containing life support systems and complex interconnection nodes (that would allow maximum flexibility in the future expansion and alteration of the habitat) would also be deployed in this form.

Construction methods, adaptability to the various activities within, and response to the harsh environmental conditions have generated the form of the main habitat. It consists of a circular tube 8 metres in diameter and 45 metres long that encloses 2145 cubic metres of space. The space allowance is based on research into long-term habitation in confined spaces which has found that a minimum design volume of 120 cubic metres per inhabitant is required. The open-plan volume that forms the habitat's main space has been determined the most psychologically beneficial for long-term occupation and it also makes internal fitting out easier, is flexible in use, and adaptable to later alterations. The design of the interior also allows for alteration of the facilities by the occupants who can tune the space to their own requirements (Fig. 15.5). A floor area of 547 square metres on two levels can be arranged to accommodate up to twenty-four personnel. Though this design utilises a 2.44-metre floor to ceiling height, it is not certain if this will be adequate in a one-sixth gravity environment and research and experience may yet determine future changes to room heights, space planning and furniture layouts.

The habitat zoning is dependent on function. The crew quarters are individual rooms of 12 cubic

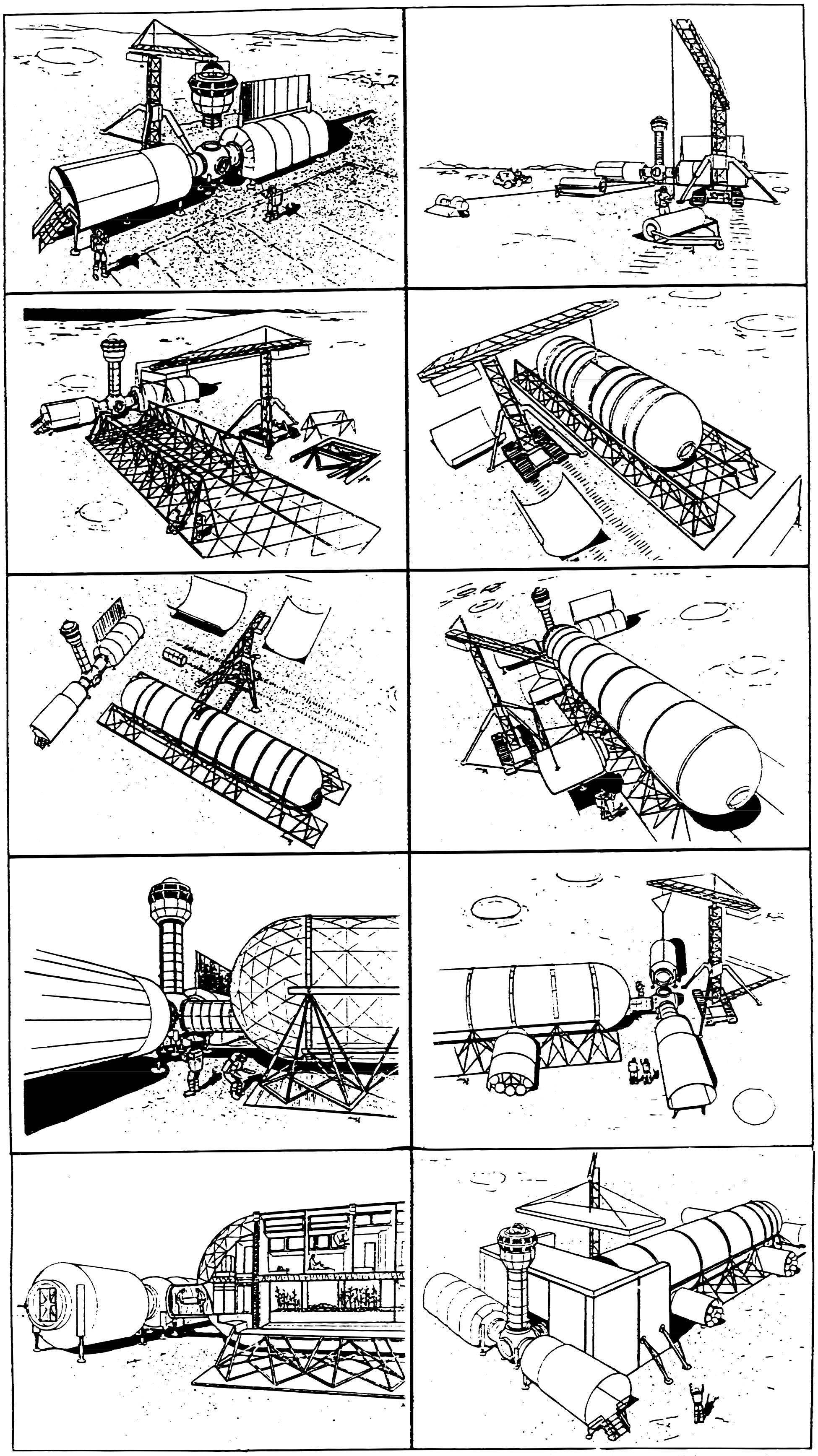


Fig. 15.6 Construction and assembly procedure.

metres which have movable modular furniture and changeable partitions of different colours and designs. Cleaning and laundry facilities are provided here as is the crew support area which has a kitchen, food storage and a leisure area. The operational level is divided into base operations where the habitat facility is monitored, and mission operations where the research work is carried out. The former contains computing, logistical and command facilities and the extra-vehicular support and maintenance facility. The latter contains all the laboratories, experimental hydroponics and a health care facility.

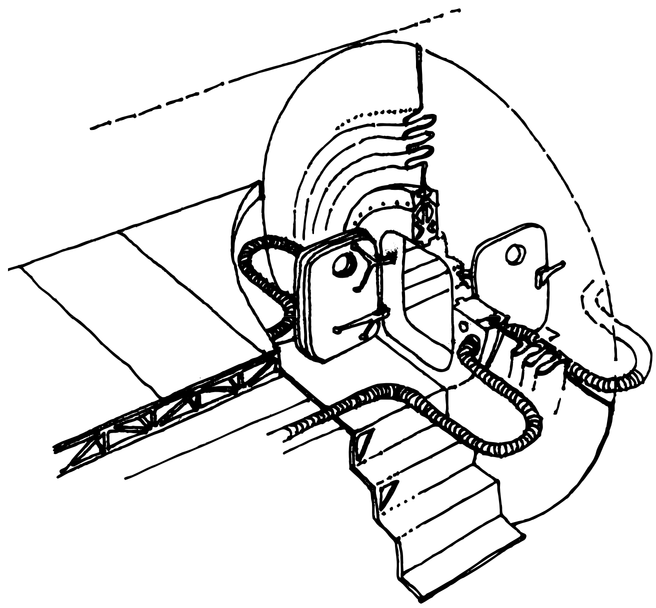


Fig. 15.7 Fabric bulkhead detail. One hatch would be continually closed when the air lock is in use to avoid catastrophic deflation of both zones. The extra folded material expands to form a concave pressure bulkhead if one of the zones became deflated.

Construction

The constructional concept for the habitat consists of three main elements, an inflatable envelope, an external support and an internal floor structure that also provides lateral bracing. The envelope is a multiple-ply, fabric skin which has an impermeable layer on the internal surface and a thermal coating on the exterior. The skin is to be made of new materials such as kevlar that combine high strength, flexibility and are lightweight. The external support structure is a modular space frame system made from high-strength materials such as magnesium alloy. This structure is fixed to the envelope at forty points where it is also connected to the internal structure. The internal support pallet is a space frame made of aluminium lithium alloy.

The construction process would begin with the grading of the site to a level surface. Onto this would be laid out a pair of continuous mats to spread the load of the support structure (Fig. 15.6). Once the support structure is erected the inflatable envelope is placed in position and attached to the forty connection points. The internal structural supports and the life support distribution systems would be prepackaged inside the habitat envelope to reduce the number of site joints. After inflation and testing the air locks and service modules would be connected. Internal fitting out then takes place in a secure controlled environment. The single large volume is split into the four distinct areas divided by function and level of privacy and noise. The habitat is also divided by a fabric pressure bulkhead in case of a cataclysmic deflation (Fig. 15.7).

Though the basic structure of the building is air-tight and fully serviced it also requires some additional external building work to secure its permanent safe operation. The variation in temperature in lunar light and shade varies dramatically. Without modification this would mean that in daylight there would be too much heat in the habitat, and at night there would be unacceptable heat loss. It will therefore be necessary to incorporate a solar panel that will store heat in the day and redistribute it at night, and a radiator that will transfer excess heat to space. A problem common to the operation of the solar radiator and to the structure of the habitat itself is protection from the micro-meteorites which constantly bombard the lunar surface. This microscopic debris could cause damage if protection was not provided. The crew would also need to be protected from galactic and solar flare radiation. Two possible design solutions have been identified. Lunar regolith encased in tubes could be wound around the buildings to provide a protective layer. Another method would be to manufacture 1-metre thick modular panels from minerals and regolith found near the site. These could then be fitted to a framework around the shelter which would also provide shade and assistance in the maintenance of a constant temperature (Fig. 15.8).

This modular pattern of building establishes a pattern of construction which could be repeated with additional inflatables, either in the pattern

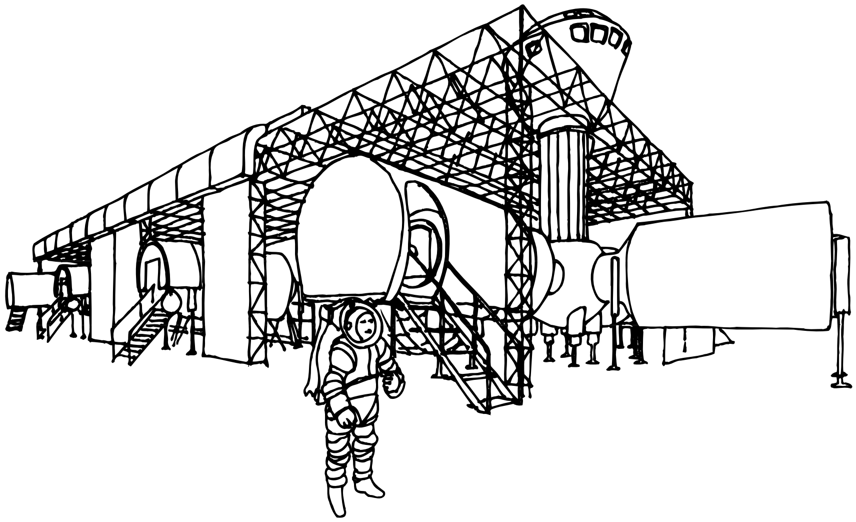


Fig. 15.8 The completed habitat with the inflatable section completely covered by shielding made from lunar regolith.

described or in a series of alternative shapes that would be redesigned to accommodate new functions and updated experience. Other patterns which have been explored include a vertical cylinder, torus and hybrid shapes. Other constructional systems have also been suggested. One proposal utilises a series of small modules fitted together, though this means that large volumes will not be possible. Componentised systems can be assembled to make larger volume structures; however, these have significant logistical assembly problems with many joints and heavy transportable mass. The total estimated weight for the inflatable habitat described here is 77,355 kilograms not including consumables, crew or spare parts. Its low mass and small transported volume, relatively simple site assembly and large deployed volume are all distinct advantages.

The spin-offs that have resulted from technology developed for space exploration have been significant. Aluminium lithium and kevlar are new materials currently in use in the aerospace industry. Though they have been used first in situations where safety and logistics are more important than cost, research and exploration of these materials in specialist applications may subsequently be of use in more conventional situations. This phenomenon does not only apply to materials science but construction and assembly techniques – for example those that use automated systems and robotics. A simple to erect structure designed for space could also have transfer technology applications where similar attributes are of value on Earth. The examination of habitation in remote environments with harsh environmental conditions has many parallells in terrestrial situations. The US National Science Foundation is examining the possibility of using inflatable habitats similar to the one described here for their Antarctic operations. Polar regions and undersea situations have been used for testing lunar exploration habitats and, consequently, knowledge of harsh environment building on Earth has improved. Self-contained environmental systems are informing scientists about the way that the Earth's environment operates and how human interaction and operations can affect it, sometimes for the better, but unfortunately, mostly for the worse. Projects like this begin to break the dependency on Earth systems and establishes a new evolutionary exploration path that has unlimited potential.

Research without direct precedent is an essential component of space research, but hardly present at all in the building industry in which there are many solutions available for a particular constructional issue, though none may be the best possible. Making use of innovative research from other areas is important, though it is sometimes difficult to recognise the benefits when the application is from a completely different sphere of design. Extra-terrestrial habitation strategies can still be perceived as building construction, though they are undoubtedly highly specialised with circumstances of site and erection that could hardly be more different from those seen on Earth. Nevertheless, if they can be appreciated, there are sufficient similarities between the functional and constructional issues in both situations to allow technology transfer to take place. The resultant benefits for construction technology in the building industry could be substantial.

ISS TransHAB

The mobile deployable space habitat that is closest to commissioning is NASA's Transit Habitat (TransHAB). This project originally began as a design for the pressurised component of a future Mars transit vehicle. The return journey from Earth to Mars will take up to 6 months each way and it is essential that during this time the travellers have safe and conducive environments on board their spacecraft in which to rest and work. The physical and psychological demands of this journey will be more extreme than any previously attempted and the creation of relatively spacious comfortable living spaces is extremely important; however, the payload necessary to build such large volumes in space from conventional rigid technology would be enormous. The inflatable solution developed for TransHAB makes possible the creation of a relatively lightweight structure manufactured in optimum construction conditions on earth. This can be transported in compact form in the payload bay of the Space Shuttle and then easily deployed with minimum assembly operations into a much bigger volume in space. It has also been designed so that it could be deployed on a remote planet's surface as part of a long-term base.

TransHAB is still a component of the future Mars mission, however, the increased emphasis on the International Space Station (ISS) has found it a new, more urgent role. The same characteristics that make the design an important part of the Mars mission make it attractive for use as part of the ISS complex – in particular, at 12.19 metres long by 8.23 metres diameter it provides 342 cubic metres of pressurised volume, nearly three times the habitable space of a comparable standard ISS module (Figs 15.9–15.10).

The habitat is divided into four 'floor' levels arranged around a central structural core. Three of the levels are living space – galley/wardroom and soft stowage on level 1, crew quarters and mechanical equipment room on level 2, crew health care/body cleansing and additional stowage on level

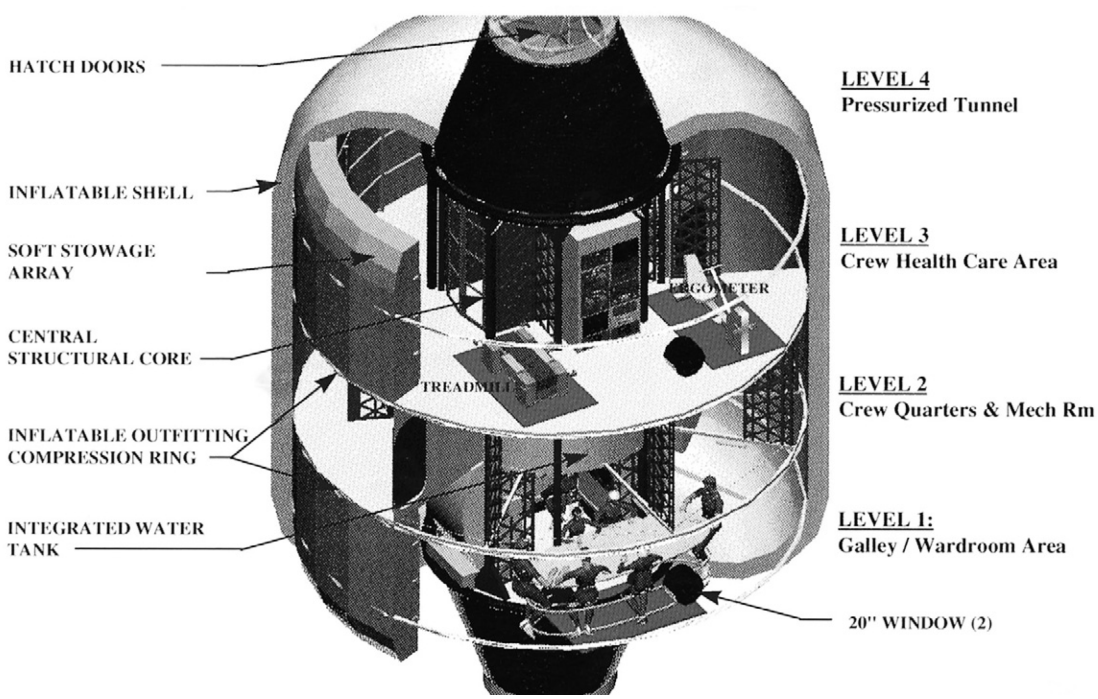


Fig. 15.9 TransHAB three-dimensional cutaway view.

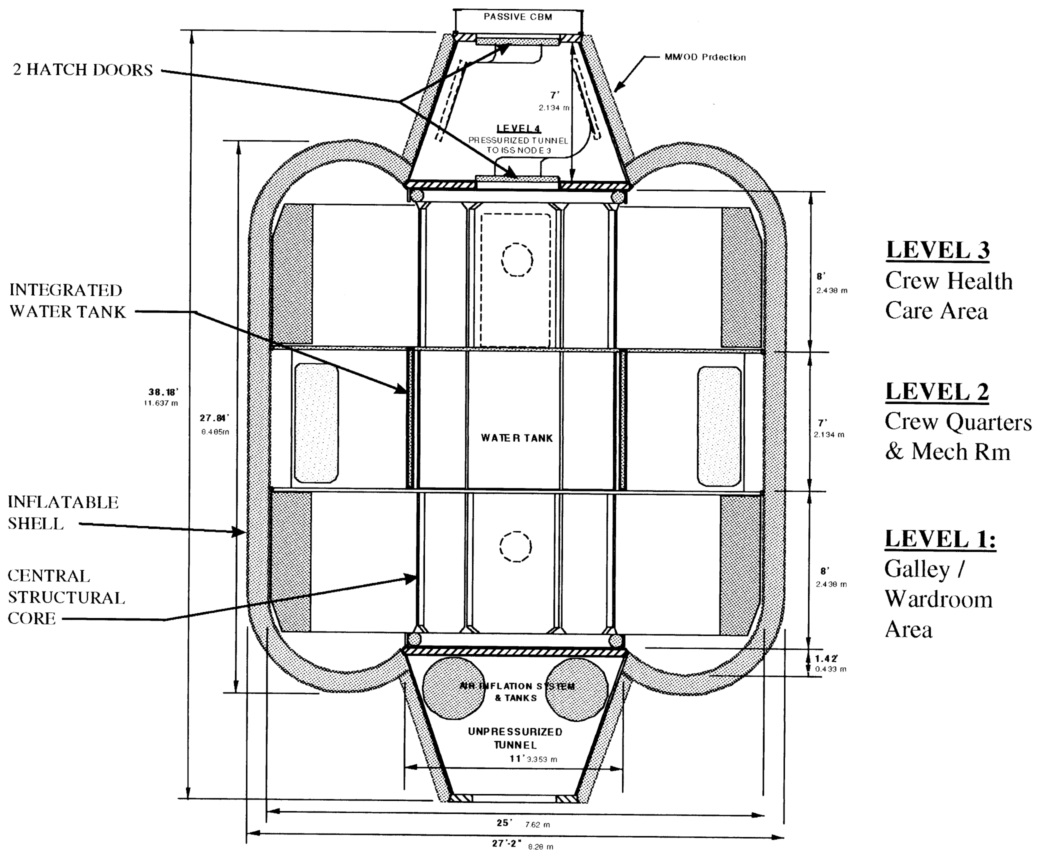


Fig. 15.10
Cross-section.

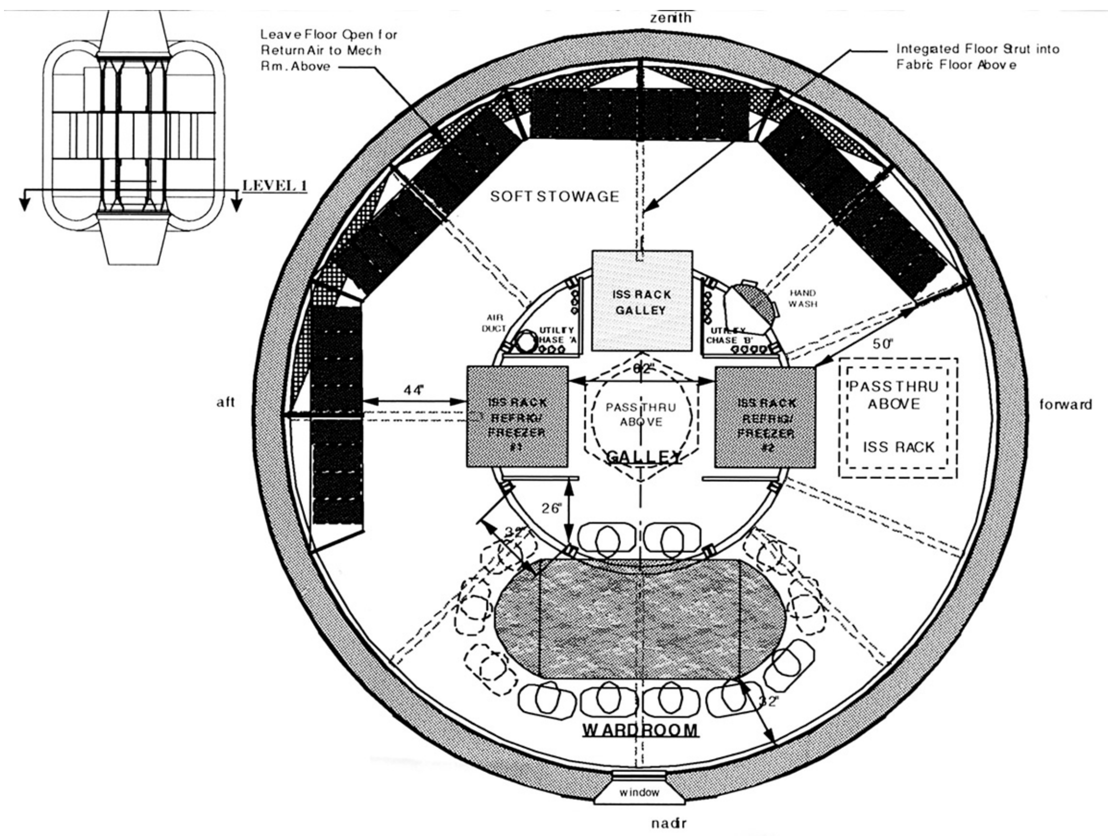


Fig. 15.11
Level 1.

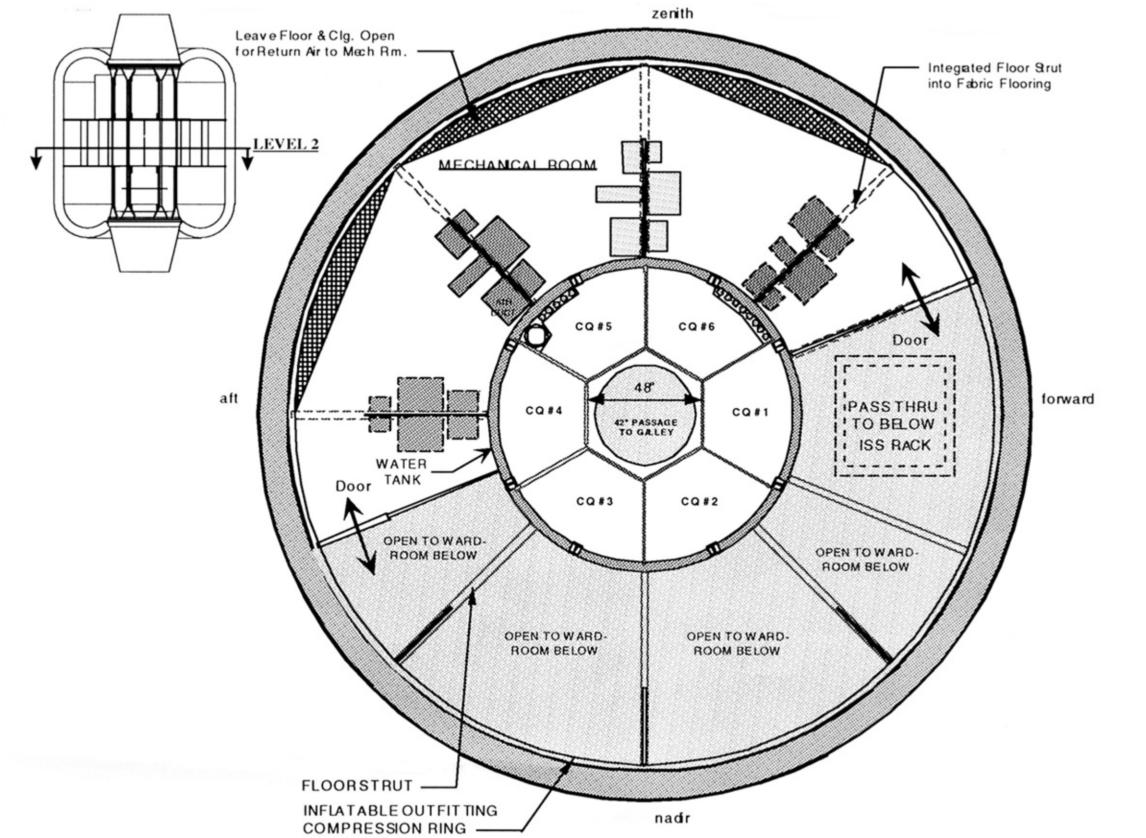


Fig. 15.12 Level 2.

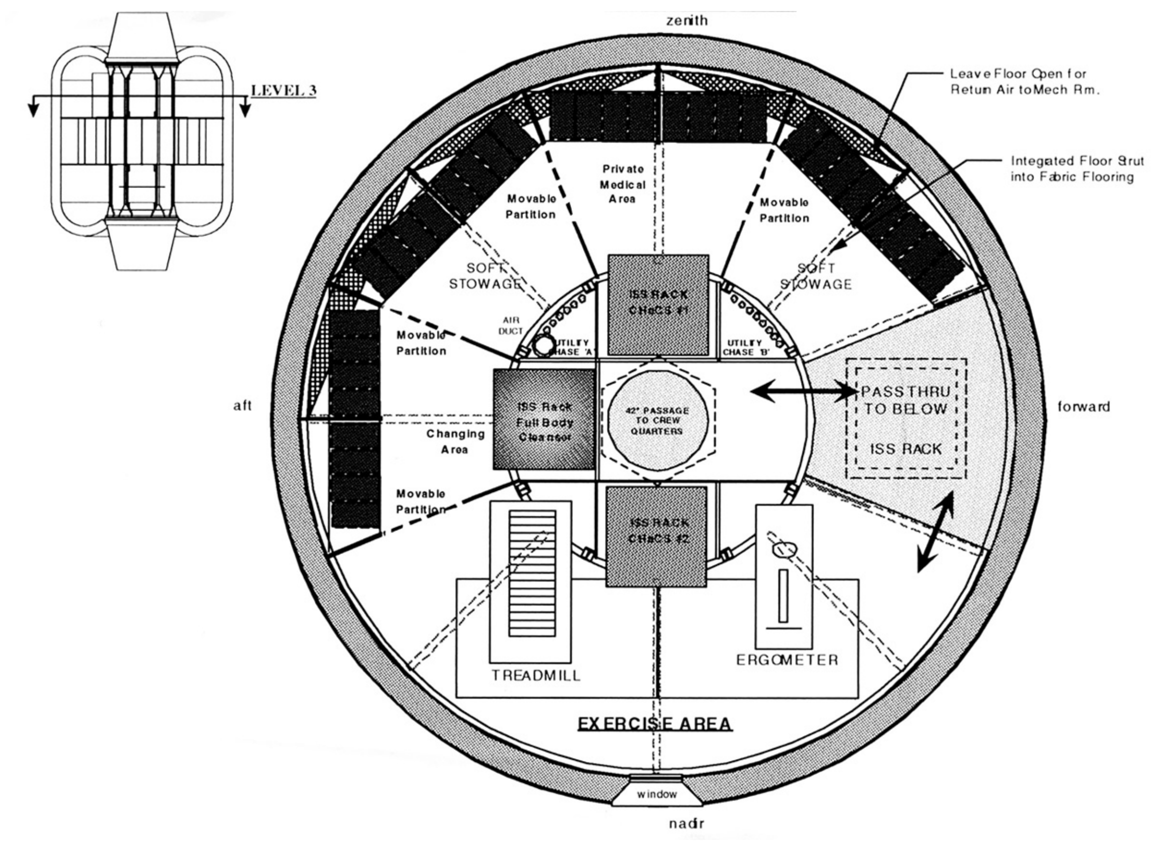


Fig. 15.13 Level 3.

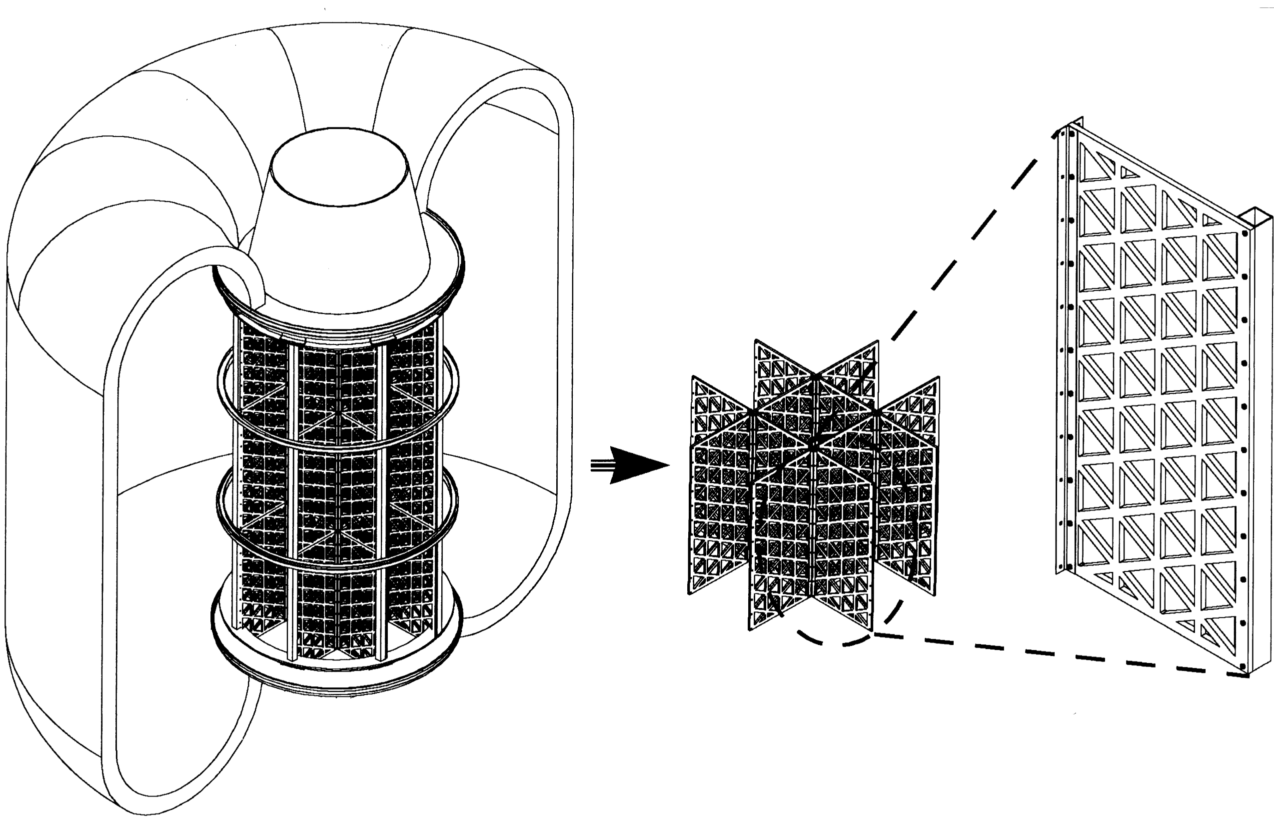


Fig. 15.14 Central core structural system.

3 (Figs 15.11–15.13). As well as a central passageway through the core, these three areas are linked by an 'atrium'-type space, providing a more open feel than would normally be expected from the cramped confines of previous space vessel designs. The fourth level is a pressurised connecting tunnel to the rest of ISS. The habitat is designed to be capable of use by the maximum ISS twelve-person crew which occurs when the shuttle is docked for crew exchange – for example, everyone can 'sit' together in the wardroom area. It also sleeps six people, each with their own private quarters with personal item storage, sleeping space and entertainment/work station. This zone is also protected from excessive radiation during solar events by a water jacket. All the spaces are designed to utilise the standard rack systems that have been created for ISS – Full Body Cleansing Compartment (FBCC), Environmental Control and Life Support Systems (ECLSS), Crew Health Care Systems (CHeCS), communications, galley, refrigerator/freezer.

TransHAB's structure is a hybrid system that incorporates both inflatable and hard technologies to fulfil the peculiar, conflicting requirements of portability versus resistance to extreme environmental conditions. It thereby combines the safety and compatibility advantages of the rigid structure with the packaging and mass/volume efficiencies of the inflatable structure. The structural core consists of a hexagonal-shaped tube made of composite longerons (columns) that connect to a tunnel unit at one end and a bulkhead at the other (Fig. 15.14). These are braced by isogrid shelves which help the core resist the launch loads but which can be repositioned after inflation to support floor beams and equipment. The inflatable shell is a multiple design consisting of four sets of layer systems, each with its own function – the internal barrier and bladder, the structural restraint layer, the micrometeoroid/orbital debris shield, and the thermal protection blanket. The inner layer of Nomex provides fire retardance and abrasion resistance – three plastic bladders form redundant air seals and four levels of kevlar felt provide for evacuation of the shell between layers when the shell is packaged after testing prior to launch. The restraint layer is woven from 25 mm wide kelvar straps specially developed to achieve more than 90% efficiency.

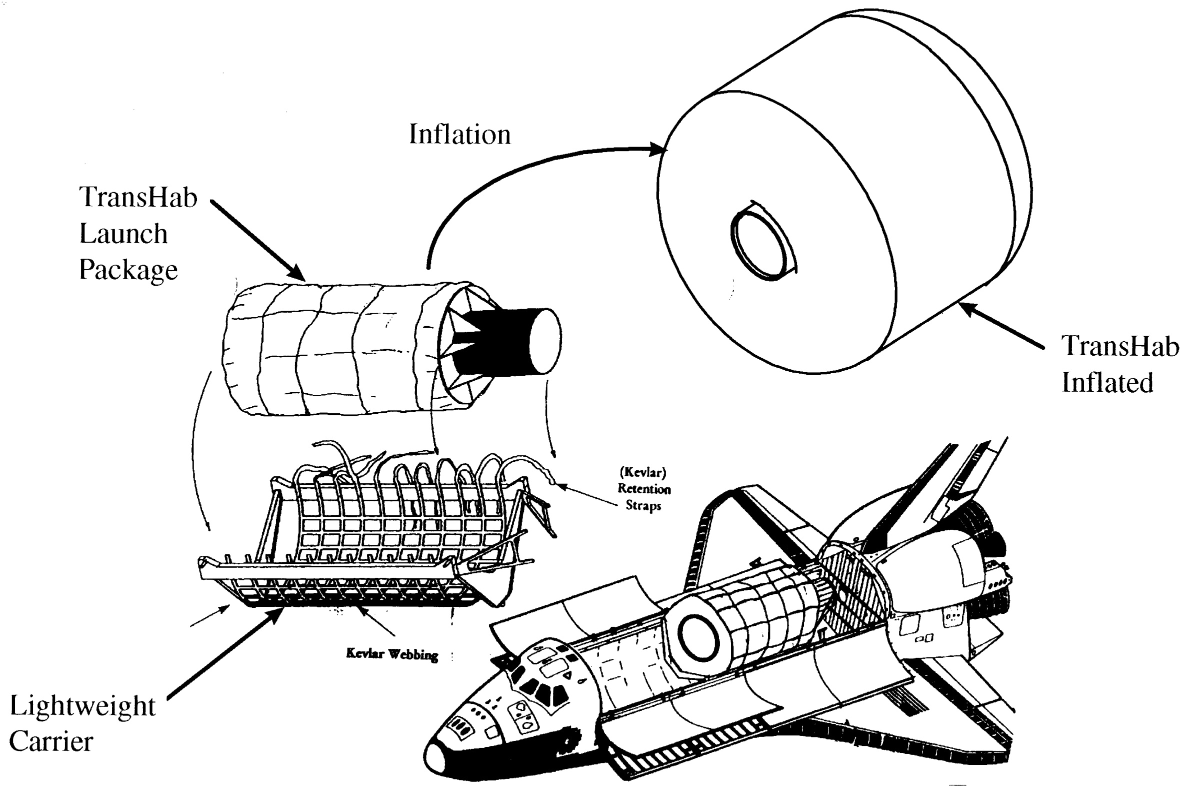


Fig. 15.15 TransHAB deployment sequence.

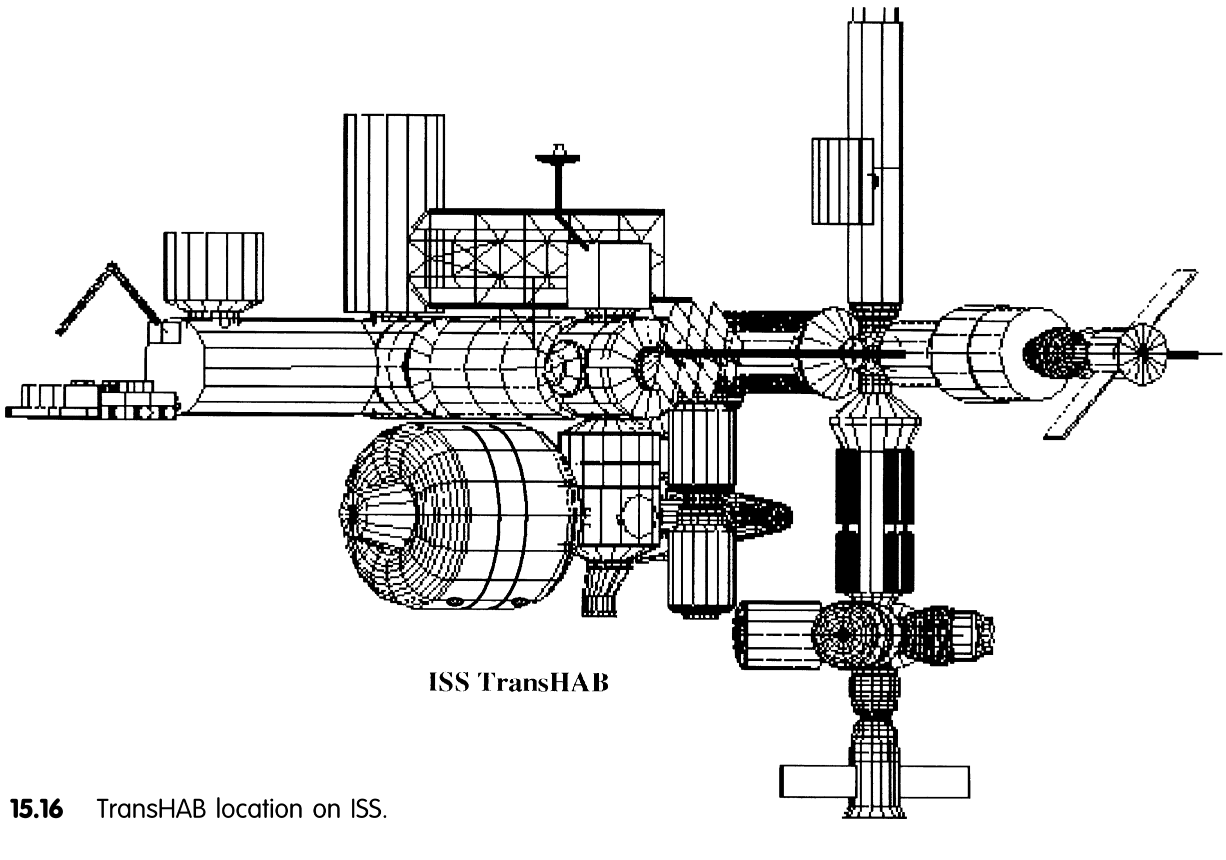
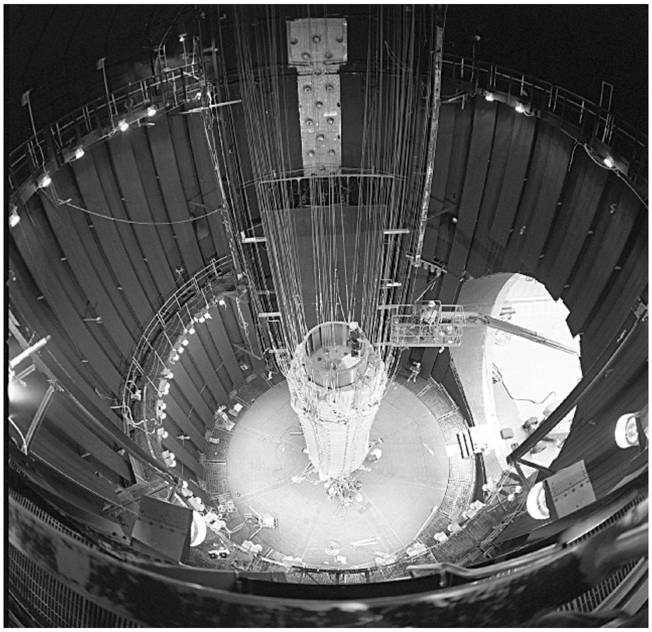
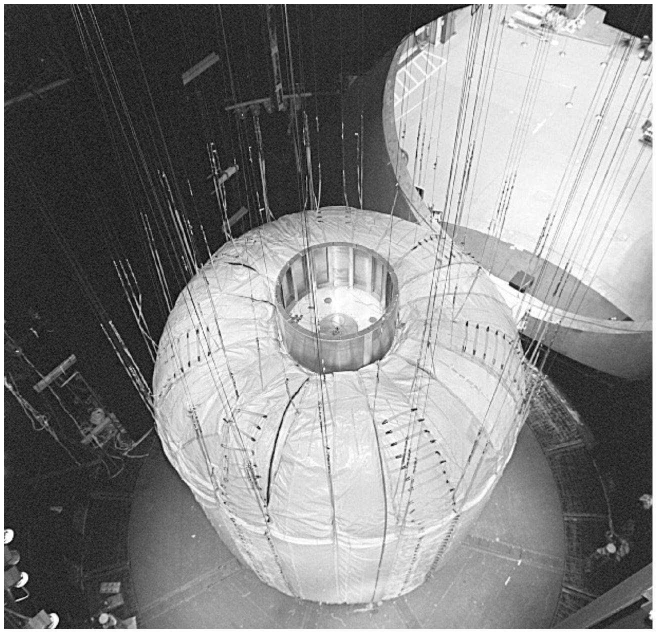


Fig. 15.16 TransHAB location on ISS.





Figs. 15.17 and 15.18 The first inflation of the full-size prototype at the Johnson Space Center, Houston, USA, 17 November 1998.

The assembly is designed to contain four atmospheres of air pressure and each cylindrical strip has been tested to 12,500 pounds (5670 kg). The protection layer has to resist particle strikes at extremely high velocities. The design philosophy is to incorporate a series of four Nextel ceramic fibre fabric layers which absorb the energy and cause the particle to disintegrate as it moves through the successive barriers. A final backing layer of kevlar provides the last line of resistance. This system has been found in testing to resist impacts by a 17 mm ball fired at 7 km/s (15,600 mph or 25,105 kph).

The TransHAB is transported into Earth orbit in the Shuttle's payload bay packaged within a lightweight kevlar webbing container. Once the Shuttle docks with the ISS the TransHAB is removed from the bay (Fig. 15.15) and fixed to one of the station's modular nodes via the passageway at the end of the structural core (Fig. 15.16). This will become the pressurised entry into the TransHAB. A similar unpressurised tunnel at the other end of the core contains the air inflation system for the outer shell which maintains its operating pressure of 14.7 psi. The internal fabric floors can then be deployed, the shelves repositioned, the equipment commissioned and the habitat occupied.

The Advanced Programs Office, Johnson Space Centre, Houston, made the first full-scale prototype unit of TransHAB in-house and it was first inflated to operating pressure in November 1998 (Figs 15.17, 15.18). The operational facility will also be made in-house, though the central core will be made by Alenia, Italy, and the internal bladder made by ILC Dover Inc. The decision to use TransHAB as the primary US habitat on ISS is subject to the satisfactory outcome of the current testing programme and, of course, continued US government funding for the space programme. However, if the system functions as expected its first launch could be as early as July 2004. This first module will be used to form a safe living and working environment aboard ISS, but also for testing the effects on the crew of long-term space travel. Parts of the technology used in the development of TransHAB are already used in several US Defense Department scenarios, such as high-performance rapid deployment shelters, but the construction stragies developed specifically for this project also have potential for use in other terrestrial situations, for example as a fuel tank, an underwater shelter, and as a divers' mobile hyperbaric decompression chamber.

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Diamond Mine Investigation Camp, Northwest Territories, Canada

Date: **1993**
Client: **BHP Minerals**
Designer: **Weatherhaven Resources Ltd, Burnaby, British Columbia, Canada**
Constructor: **Weatherhaven Resources Ltd, Burnaby, British Columbia, Canada**

An important factor in the creation of successful portable architecture is that the comprehensive nature of the task is understood. Conventional building construction commonly utilises a wide variety of services, expertise and suppliers, often provided by many different organisations and businesses. It is based on the historic system of guilds and trade organisations which has resulted in a subcontracting procedure in which different companies with different expertise collaborate to construct a building. Some specialist companies who include a range of trades within their organisation now exist, though these usually restrict their activities to a particular building type such as housing. More usually, the design team will consist of several different practices, each with different areas of expertise, and the main contractor will employ a wide range of specialist subcontractors though these may also have different, and sometimes conflicting, responsibilities to client and architect. Materials suppliers and manufacturers are also usually separate organisations which will use independent delivery companies to transport components and materials. Any building process is necessarily complex, however, it is made more so by the unnecessary interrelationship of many different parties, even though they may all have a common objective.

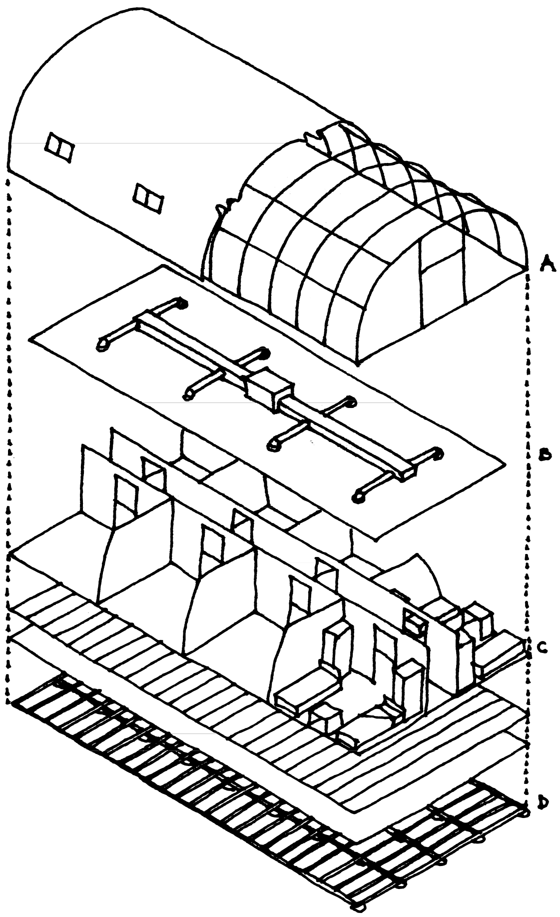

Fig. 16.1 Weatherhaven Resources Ltd, 'Series 4' Shelter. The shelter has many different layout and environmental options.
(A) structural frame and cladding membrane,
(B) optional suspended ceiling with environmental control equipment,
(C) internal partitioning and furniture, (D) different floor options include waterproof insulated membrane, insulated panel system in steel or plywood and suspended deck.

Product design has an established history of objects that have been designed and constructed within the same organisation for delivery in completed form, ready for operation. In vehicle design there are many examples of cars, service vehicles, aircraft, ships and trains that have become classic examples of a fine-tuned response to a specific problem. The idea of building as product design has been explored, but hardly ever fully implemented. The method of making buildings by using the process of coordinated, factory-based manufacture has dramatic advantages in terms of construction speed and efficiency, however, as in product manufacture it is very important that design remains tuned to user and client requirements so that quality is not eroded. Where speed of erection has been of paramount importance, proprietary design and build packages have been used, though with varying degrees of success. For permanent buildings that will be situated in important locations for many years it is doubtful that the advantages of speedy erection can ever outweigh the risks of inappropriate intervention in both the urban and rural environment. The dedicated design solution is therefore an integral component in the achievement of an appropriate response to individual functional and siting issues.

Building for temporary deployment on a remote site has different design parameters to building permanent long-term structures. In portable building, the advantages of a holistic approach to design and construction can be easily understood. To build conventionally in a remote location is in many cases impossible. Components and materials transportation must be carefully considered and all construction must be carried out by a dedicated on-site team whose shelter and provisions must also be provided. Foresight and planning are essential as mistakes and omissions in the design are far less easily solved when the design team, component manufacturer and materials supplier are at a great distance. If the building also has to be erected in extreme conditions or is required to be in use quickly, the advantages of integrated design and construction become more relevant. The building may also have to be capable of re-erection at other sites for logistical or economic reasons, in which case this streamlined efficient construction process becomes an essential rather than a desirable characteristic of a successful project.

One of the most experienced providers of shelter buildings for remote locations is Weatherhaven Resources Ltd, a Canadian company founded in 1981 by the merging of two separate businesses – an expedition organising team and a Vancouver-based construction company. The founders recognised the need for a dedicated approach to the provision of temporary shelter in remote places and developed a strategy that provided a complete service. This included design, manufacture, packaging, transportation and erection of buildings, all of which would be created specifically to respond to the logistical problems of remote deployment in harsh environments.

Although Weatherhaven recognised that different situations would require different strategic and constructional solutions they also understood that the development of a core building system adaptable for use in many different ways would have production and deployment advantages. The use of universal components results in economies of repetitive manufacture and the logistical advantages of a modular erection process. The first system devised was the 'Series 4' shelter, a simple and rugged modular portable building that could be used in a number of different forms depending on specification (Fig. 16.1). The building is similar in form to the Nissen hut (which was also designed by a Canadian, Captain P.N. Nissen of the Canadian Engineers) and also utilises the principle of common modular components for ease of construction and erection. However, the details of the Weatherhaven buildings are quite different, resulting in a much more adaptable and flexible design which is lighter and easier to transport. The structure consists of a set of pre-curved tubular arches, none of which is longer than 1.8 metres, that can be assembled by hand into a continuous arch. The arch is restrained from spreading by a base frame made from the same material which can either be free standing, anchored into the ground (or ice), or fixed to a hard floor plate. The structure is made from aluminium for spans up to 4.88 metres and zinc-plated steel up to a maximum span of 9.15 metres. The length of the building is infinitely extendible in 1.2 metre (four foot, hence the name 'Series 4') increments based on the arch bay size, and several buildings can be connected by enclosed walkways in very cold climates. The frame parts are interchangeable and have slip-on fittings that do not require special tools for connection. The weatherproof membrane is made from vinyl-coated polyester made in three pieces, a rectangular top panel and two shaped ends, and is deployed after the frame has been erected by pulling it over the curved roof. The simplicity of the building form and the careful logistical arrangements associated with its installation ensures that the system is reliable.

Fig. 16.2 'Series 4' erection procedure. In this project an insulated prefabricated plywood floor has been laid. The floor level framing is in place and erection of the arched structure is underway.

A multitude of variations can be added to the basic shelter that enable it to be used in many different situations and be adapted to virtually any environment. Windows and doors are available in a wide range of patterns from simple flaps to sliding glass screens. Soft floor systems from a simple polyethylene ground sheet to an insulated arctic grade foam-filled material are available. Hard floors can be made in situ where possible, either with local timber or more sophisticated imported systems utilising stressed-skin hollow plywood panels filled with foam (Fig. 16.2). For more rugged situations a composite foam-filled, steel skin system can be included in the delivered package. A steel skid frame or lifting pallet for relocating the building once erected is also available. The weatherproof membrane can also be supplemented by additional layers that mitigate extremes of temperature. 'Polytherm' mass insulation is used for cold climates and 'Reflectix' bubble packs are used to retard excessive heat build-up in hot climates. Extra rigid tube or wire bracing can be incorporated for high wind load situations. A workshop version is also available with large openings for vehicle entry and special components such as exhaust ports.

One of the most important features of the Weatherhaven strategy is the packaging and assembly system that the designers have devised. All components are delivered in a package which is specially prepared, dependent on the contents and transportation system. Soft vinyl bags, metal boxes with carrying handles and wooden crates are all used. Each package contains all the components necessary to complete a particular task so parts identification and location is simplified. A 'universal crate' system has been devised based on the dimensions of a standard ISO shipping container. It uses a system of modular sized packages that also relates to other modes of transport – different aircraft cargo holds, helicopter lifts, trucks and motorised ice sledges. Weight and packed volume are crucial considerations for portable buildings. The standard aluminium shelter weighs 5.9 kilograms per square metre of floor area and 32 square metres of uninsulated building can be packed into one cubic metre. Insulation adds bulk (about 15 square metres per cubic metre) but little extra weight. The steel-framed building is about a third heavier.

A wide range of servicing and furnishing packs have been created to allow the shelter to be used in many different ways. These are also designed for rapid installation and dismantling. A pre-harnessed system that uses flexible waterproof wiring can be installed in a single box with all the components necessary for one building. Generators are installed

Fig. 16.3 'Series 8' floor being made in a warm climate situation.

in series to allow for small power output at off-peak periods. This conserves fuel – particularly important in remote situations where transportation costs are high. Mechanical systems such as heating, cooling and hot and cold water supply follow a similar philosophy but in many cases, may need to be even more specialised due to the difficult environmental conditions. Snow and ice melters may be required to provide water which must then be filtered for use. Storage facilities may have to be comparatively large, and pumps are required to circulate water from ground-level tanks. All hygiene and washing facilities use simplified plumbing that must be watertight but demountable for moving. Waste and effluent needs to be treated and sometimes stored and transported away from environmentally sensitive areas. Heating may use propane gas, electricity, or be oil-fired and there may also be a need for humidity control systems for sensitive equipment. Weatherhaven design much of their own equipment based on experience and feedback from their clients and their own sponsored expeditions.

Though the 'Series 4' shelter embodies all the main features of the Weatherhaven system the company have devised other buildings that respond to specific functional environmental and logistical problems. The 'Series 8' shelter is similar to the 'Series 4' but is built using fewer components, on a 2.44 metre (eight foot) bay size to allow easier and faster erection with less labour (Fig. 16.3). It is designed primarily for tropical and hot country situations and utilises a special reflective vinyl-coated polyester membrane that is made in one piece for fast deployment and reflects much of the sun's infrared energy for a cooler internal environment. It also has large screened openings with sun shades that induce cross-ventilation. In desert situations where there is a high temperature difference between day and night a thermal cap may be installed inside the building at roof level, reducing internal temperatures during the day and retaining heat at night.

Similar in form to the 'Series 4' and 'Series 8' are the much larger 'Widespan' structures. The problems of making demountable large span and large volume buildings have been solved with an ingenious construction strategy. The 'Widespan' structures are available in 15.24 metre and 21.33 metre spans and are designed to be assembled without any heavy equipment or cranes and without the crew having to leave the ground even though the buildings are up to 9.45 metres high. The erection principle is similar to that utilised by the German Hünnebeck Hangars and the USAAF aircraft hangars made by the Butler Manufacturing Company, both made during the Second World War. In these examples a steel three-pinned arch was assembled flat on the ground and the ends drawn together to form a clear span space beneath. A canvas tent, hung beneath the truss, formed the shelter membrane. Weatherhaven have improved on these examples in several ways. No component is more than 3.66 metres long or weighs more than 68 kilograms which means that all parts can be carried by people rather than machines and the entire structure can be fitted into a single ISO shipping container for easy transportation.

Fig. 16.4 A remote base created primarily from the 'Series '4' shelter system. All units are linked with enclosed corridors.

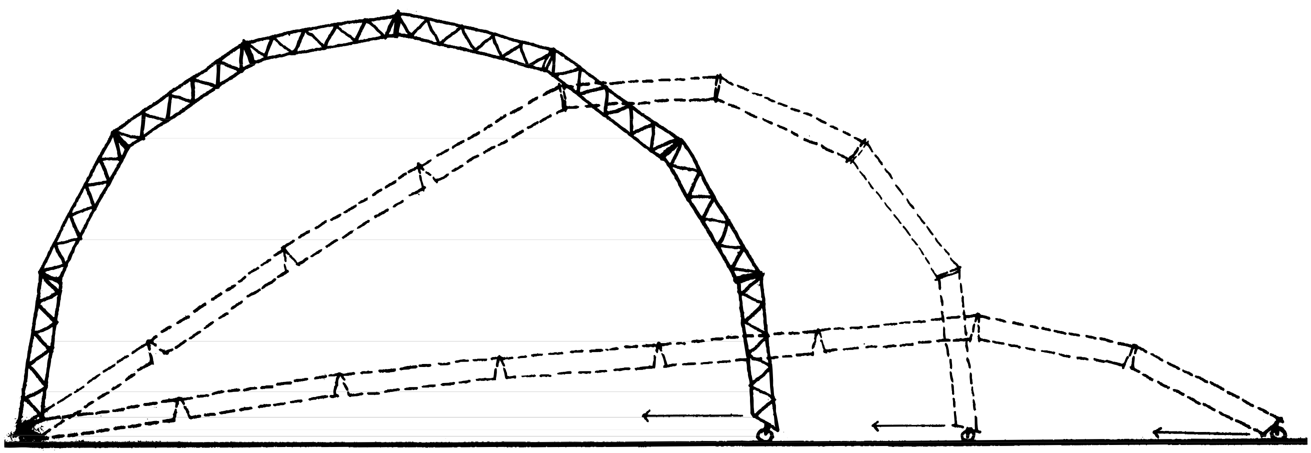

Fig. 16.5 'Widespan' mobile large-volume building, erection procedure.

All assembly procedures are carried out on the ground. The truss components are laid out and pinned together to form the arches and the longitudinal cross-bracing is fixed between the truss segments with clevis pins. Wheels and base plates are fixed at the ends of the arches. The weatherproof membrane is then laid out on top of the assembly in modular 3.66-metre widths that correspond to the bay size. An overlapping weather seam is connected at the joints and the end wall components are fixed to the arches. One person operates a manual winch at each arch position to erect the building, pulling a cable tight between the two ends which draws them together. When the building reaches its fully erect profile the cover membrane becomes taut and the arch bases are fixed down with ground anchors, after which the winches and cables can be removed (see Fig. 16.5). The entire 465 square metre building can be deployed by four men in one day using simple hand-held tools. As with all Weatherhaven buildings, the structure is positioned on the inside of the membrane, protecting it from the weather, helping to reduce cold bridges, and providing a frame for support of services and internal partitioning. The building can incorporate a wide range of windows, doors, skin insulation, and services and its average weight is 20 kilograms per square metre of ground area – a 465 square metre building therefore weighs only 9300 kilograms.

The most mobile of Weatherhaven's products is the 'Mobile Work Camp' (MWC) which is designed specifically for very extreme environmental conditions where frequent base relocation is required and conventional quick strike shelter will not provide sufficient protection (Fig. 16.6). This shelter is capable of transportation without being demounted which means that it can be moved on a day-to-day basis between different work locations. It also means that a secure place of protection is always available for the team members and that more time can be spent carrying out the expedition tasks instead of erecting and dismantling accommodation. The structure is based on a steel frame which is assembled on skis, or in desert situations on trailer wheels. The shelter is formed from a lightweight curved arch and vinyl membrane which is fixed to the base frame. The light weight of the structure means that small towing vehicles that use less fuel can be used – a single unit can be pulled by a motorised snow bike. A complete sleeping, eating, working environment available at all times in the worst conditions can therefore be towed behind the transport vehicle. The unit has also been tested for deployment by helicopter whilst flying at speeds of up to 60 knots.

The design of the most sophisticated Weatherhaven building, the 'Mobile Expandible Container Camp' (MECC) has been informed by the search for a higher performance, instantly available facility (Fig. 16.7). This building incorporates a standard ISO container as its base structure which expands to three times the floor area when deployed, making it economical to transport in comparison to typical hard-walled mobile structures. The building can be handled in exactly the same way as a standard container, with all the same fixing, stacking and moving connections – cranes, trailers, fork-lift trucks can all be used to move the building in its travel mode. Once on site, the side walls fold down and become floors with adjustable legs to hold them in position. Membrane covers

Fig. 16.6 Weatherhaven Resources Ltd 'Mobile Work Camp'.

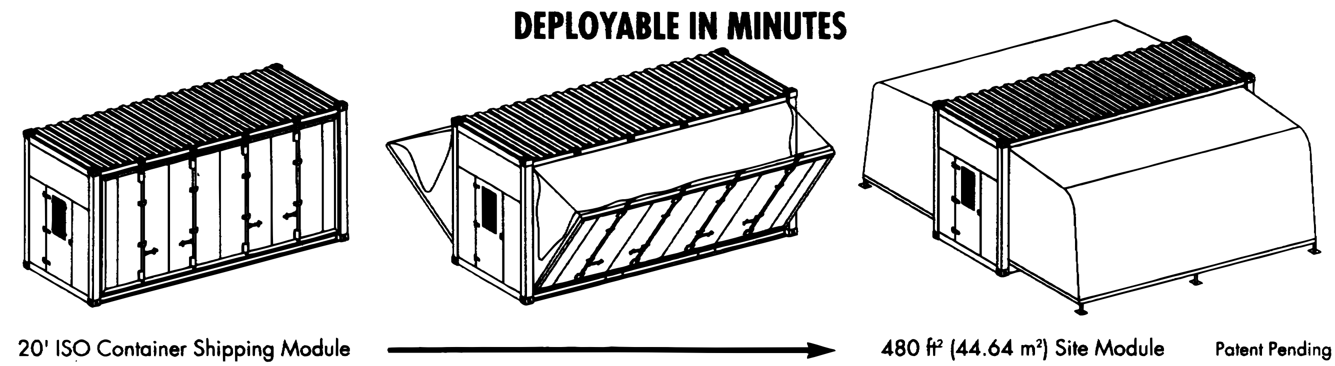

Fig. 16.7 'Mobile Expandible Container Camp'.

extend at each side and are tensioned into place with pre-stressed arches which are fixed without any tools. Doors and windows may be in the container ends or in the membrane side panels. This building is particularly suitable for high performance functions that use sophisticated equipment such as medical facilities, laboratories or communications control centres, because it has a hard floor and interior walls which are protected from damage and theft during transportation. Fixed equipment can be built into the unit and the remaining space used for storage so that when it arrives on site it can be in use within minutes. The weight of the entire unit is 3175 kilograms providing 44.64 square metres of instantly usable highly serviced building.

BHP Minerals Diamond Mine Investigation Camp

In 1993 diamond deposits were discovered in Canada's remote Northwest Territories that were thought to be the biggest in the world outside South

Africa. A dramatic race ensued accurately to locate deposits and establish operations that would enable commercial extraction processes to begin. The site environment was extremely harsh with only a brief summer period in which to establish base camp. In a race against their competitors, BHP Minerals needed to establish a facility for 110 people and their equipment, which would enable engineering operations to continue throughout the winter.

The first stage of the operation was to establish a Weatherhaven crew shelter so that a construction team could prepare a temporary landing site for heavier aircraft. A single crate was flown in by light aircraft and the building was assembled and in use within four hours. The team then prepared the camp layout and as the rest of the building components and other equipment was flown in, assembled the entire facility. All the supplies were transported on Douglas DC3 aircraft from Yellow Knife, the capital of the Northwest Territories and the nearest town for many hundreds of miles. The completed facility included sleeping and leisure accommodation, a twenty-four hour kitchen, showers and toilets, hospital, offices and engineering base, and was built in twenty working days. Many of the BHP team were able to start work in just a few days as the first buildings became available. Because of the extreme conditions, shelters were required for all the support facilities including water treatment and power supply, and heated corridors between buildings were also used to increase comfort levels and ease operational use (Fig. 16.4).

Weatherhaven products are not designed to provide solutions for architecturally sensitive sites but as an ingenious practical response to a wide range of problems that relate to shelter in extreme, usually remote, environments. They challenge preconceptions about what a building is and what it can do. The practical issues of providing safe and secure accommodation that make it possible for people to live and work in remote hostile environments has been solved by adopting the approach that the building is, above all, a tool that fulfils a functional service upon which not only the success of the operation may depend, but also the lives of its users. Many of the principles involved in the construction of these buildings are not technologically advanced, neither do they break new ground in terms of materials or techniques. Weatherhaven's design strategies and operation methods are remarkable for the organisational and logistical approach that they take. Though the clients can determine the task that their operatives will have to undertake and the location in which they must be based, Weatherhaven draw on their own experience which involves dedicated research and product proving, to assess shelter requirements and respond with an appropriate building proposal. This is generally in the form of a comprehensive solution – everything from design, materials sourcing, manufacture, packaging, transportation and construction services can be provided within the one organisation. The company has access to a full range of transportation systems and can arrange transport in aircraft from the small Bell 206 helicopter to the giant Antonov 124 aircraft. They will also dismantle and redeploy the facilities if required. Alternatively, as the principles involved in the buildings' erection are very simple, some clients opt to use just a single airlift to site at the start and end of an expedition, and assemble the facility themselves using written and video-based instructions.

Formal aesthetic architectural issues are understandably viewed with little importance in Weatherhaven's work. The impact on site is of limited duration and, in many cases, so remote as to be invisible to most of the world. The internal environment of longer stay remote shelters is, however, of some importance and besides physical comfort, the psychological impact of having communal and leisure space and the opportunity for privacy has been recognised by Weatherhaven in the design of their facilities.

It is in the area of logistical approach to the provision of portable buildings that Weatherhaven's work is of particular interest. Though their market is undoubtedly specialised, the principle of complete provision of the built package, based around tried and trusted systems that also have the flexibility to be fine-tuned to the clients' and users' needs, also has applications in the provision of less specialised portable buildings. The advantages of comprehensive design, manufacture and deployment systems are significant. In this field, design and assembly issues are much more complex and alternative construction strategies that simplify difficult problems have particular relevance. The complex nature of the problem has meant that such unconventional approaches are viewed without the prejudice found in the rest of the building industry where established practices prevail.

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