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**SICSA SPACE ARCHITECTURE  
SEMINAR LECTURE SERIES**

**PART VIII :  
SHELTER DESIGN  
AND CONSTRUCTION**

[www.sicsa.uh.edu](http://www.sicsa.uh.edu)

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**LARRY BELL, SASAKAWA INTERNATIONAL CENTER FOR SPACE ARCHITECTURE (SICSA)  
GERALD D.HINES COLLEGE OF ARCHITECTURE, UNIVERSITY OF HOUSTON, HOUSTON, TX**





The Sasakawa International Center for Space Architecture (SICSA), an organization attached to the University of Houston's Gerald D. Hines College of Architecture, offers advanced courses that address a broad range of space systems research and design topics. In 2003 SICSA and the college initiated Earth's first MS-Space Architecture degree program, an interdisciplinary 30 credit hour curriculum that is open to participants from many fields. Some students attend part-time while holding professional employment positions at NASA, affiliated aerospace corporations and other companies, while others complete their coursework more rapidly on a full-time basis.

SICSA routinely presents its publications, research and design results and other information materials on its website ([www.sicsa.uh.edu](http://www.sicsa.uh.edu)). This is done as a free service to other interested institutions and individuals throughout the world who share our interests.

This report is offered in a PowerPoint format with the dedicated intent to be useful for academic, corporate and professional organizations who wish to present it in group forums. The document is part of a series of seminar lectures that SICSA has prepared as information material for its own academic applications. We hope that these materials will also be valuable for others who share our goals to advance progress on Earth as well as in space .



The SICSA Space Architecture Seminar Lecture Series is divided into two general Lecture Groups :

**GROUP ONE:**

- Part I : Space Structures and Support Systems
- Part II : Human Adaptation and Safety in Space
- Part III : Space Transportation, Propulsion and Pathways
- Part IV : Space Mission and Facility Architectures

**GROUP TWO:**

- Part V : The History of Space Architecture
- Part VI : The Nature of Space Environments
- Part VII : Natural and Artificial Life Support
- Part VIII : Shelter Design and Construction

The SICSA Seminar Lecture Series

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**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



This part of the SICSA Seminar Series addresses different types of shelters that have been proposed and developed for a broad range of applications and environmental settings. Some, but not all, may be appropriate for extreme environments and operational conditions on Earth and in space.

This report presents diverse examples of ways shelters have been designed and constructed in the distant and recent past. Its primary purpose is to stimulate awareness of considerations and innovations that can guide contemporary planning. New possibilities are unlimited, and will continue to occur in response to changing human needs, and as products of creativity and technological progress.



Emphases of This Lecture Part

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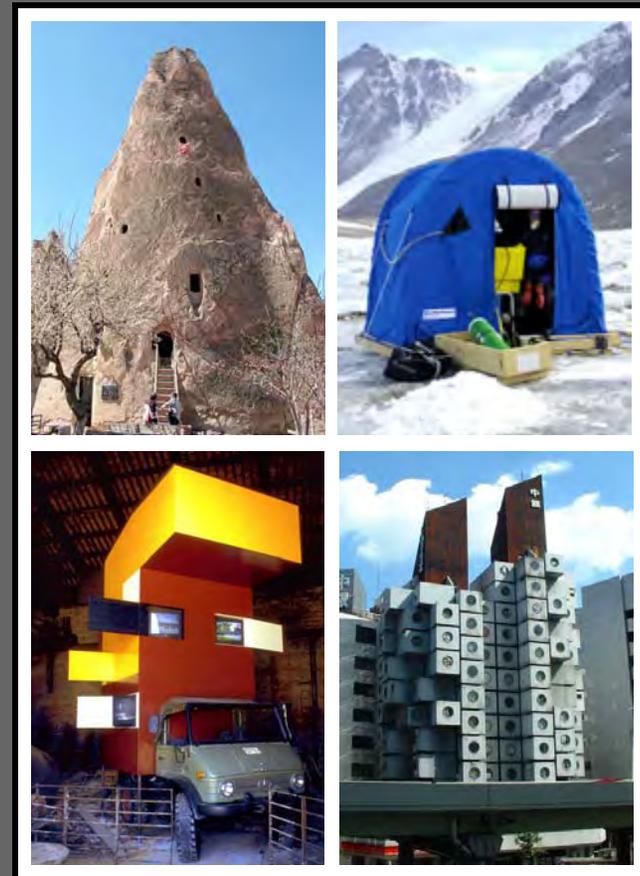
**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



While the primary emphasis of this Part shifts away from space architecture, the general topic of shelters encompasses many concepts that can be directly or indirectly applied to extreme environments and analogs which include space.

- Examples presented illustrate different design and construction approaches that address:
  - Optimization of in-situ resources to create shelters using basic materials and methods.
  - Utilization of cargo-type modular units that can be transported to remote / extreme settings and rapidly / easily deployed.
  - Towable and self-transportable habitats that are ready for occupancy with little or no site preparation or set-up time / labor.
  - Modular assemblies and complexes for expanded uses and communities.

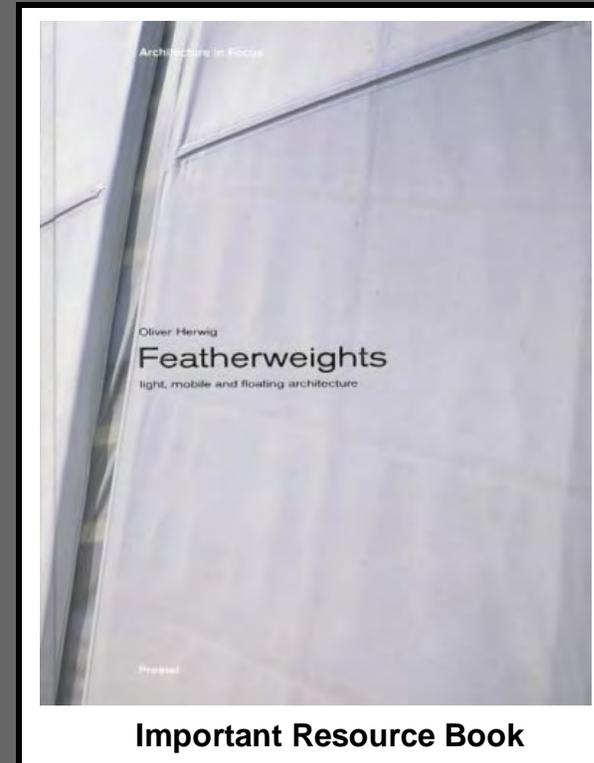


Extreme Applications / Analogs



“*Featherweights*” presents many interesting and well illustrated examples of lightweight structures of diverse sizes, types and applications including tents, inflatables, prefabricated and large-span concrete structures. Some of these shelters are portable, some are temporary, and others are permanent. The book features many innovative and noted works by distinguished designers and firms that have influenced architectural and engineering practice and which demonstrate a fusion of aesthetic and practical benefits. The book was published in 2003 by Prestel Publishing, 175 Fifth Avenue, New York, NY 10010 ([www.prestel.com](http://www.prestel.com))

Oliver Herwig



Key References

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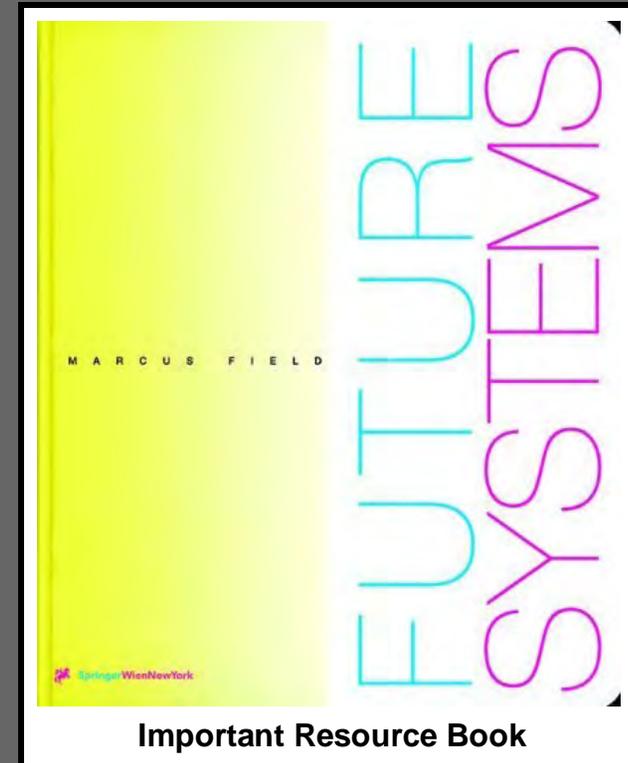
**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



“*Future Systems*” by Marcus Field features some interesting and highly innovative projects by the UK architecture firm of the same name, owned and managed by Jan Kaplicky and Amanda Levete. Some of the design proposals were created or co-produced by David Nixon, a talented US architect. In addition to the creative ideas, the projects are noteworthy for their excellent hand-drawn quality, which is truly exceptional. The book was published by the Phaidon Press, London in 1999, and is distributed in the US by the Hachette Book Group Customer Service, Three Center Plaza, Boston, MA 02108. Contact Jeremy. Raymondjack@hbusa.com/ussales@phaidon.com

Marcus Field



Important Resource Book

Key References

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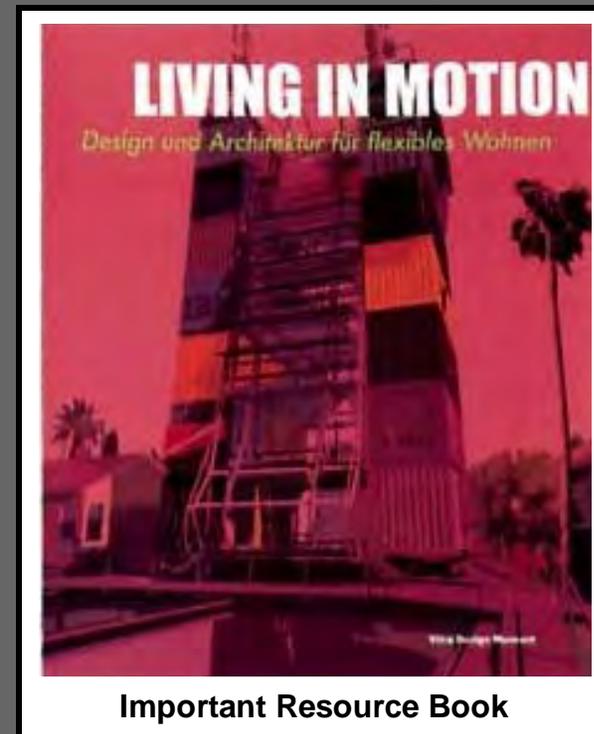
**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



“*Living in Motion*” presents and discusses examples of ways habitats have been designed for dynamic mobility from times of early nomadic lifestyles to the present. These examples include tents, houseboats, caravans, mobile home parks, transformable dwellings, knock-down houses, vehicle interiors, and even “wearable architecture.” This informative and well-illustrated book was published in 2003 by the Vitra Design Museum as an exhibition catalogue.

Vitra Design Museum



Key References

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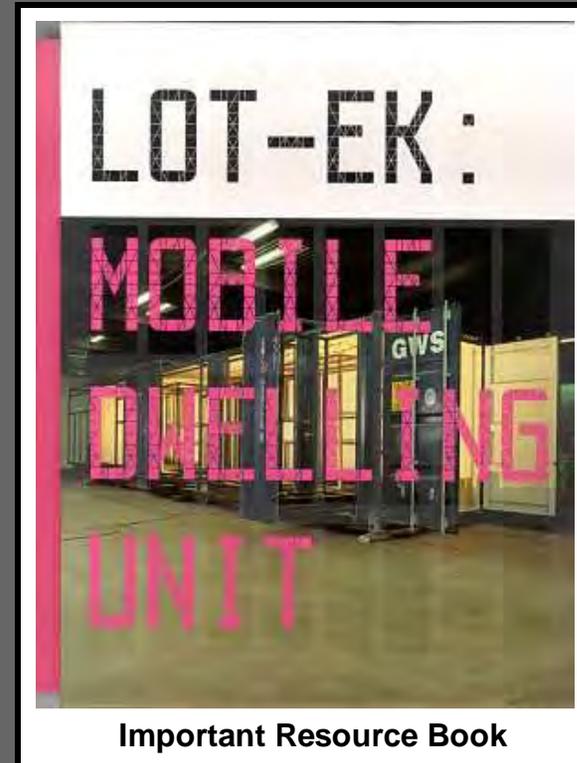
**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



LOT-EK is a New York-based architecture studio, founded by Ada Tulla and Giuseppe Ligano in 1993, which has produced diverse modular habitat proposals and projects for cultural, residential and commercial applications. Their innovative designs have received international attention through numerous exhibitions, awards and publications, and include portable stacked and expandable dwellings, public event and exhibitions facilities, stage sets and furniture. This book which presents many of their works was produced in 2003 by the University Art Museum, UCSB, Santa Barbara, California, and is published by Distributed Art Publishers (DAP), 155 Sixth Avenue, 2<sup>nd</sup> Floor, New York, NY 10013 ([www.artbook.com](http://www.artbook.com)).

University Art Museum, UCSB



Key References

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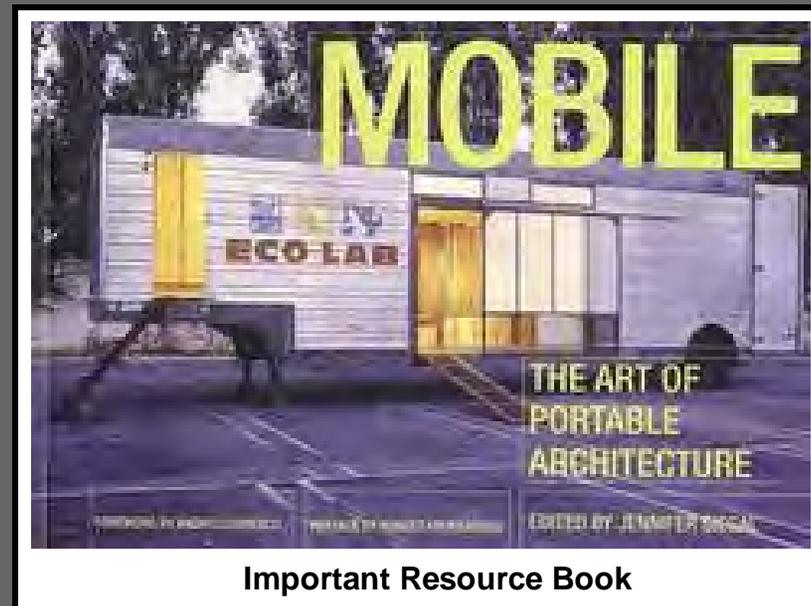
**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



*“Mobile: the Art of Portable Architecture”*, edited by Jennifer Siegal, is an informative, interesting and well-illustrated book that discusses an “age of new nomadism” which has come about as the result of recent transportation and construction technologies. The publication presents examples and descriptions of a variety of mobile, erectable and pneumatically-deployable systems that reflect and support a dynamic departure from static views of habitats and lifestyles. Published in 2002, it can be obtained from the Princeton Architectural Press, 37 East Seventh Street, New York, NY 10003 (see [www.papress.com](http://www.papress.com) for a catalog of available books).

Jennifer Siegal



**Important Resource Book**

Key References

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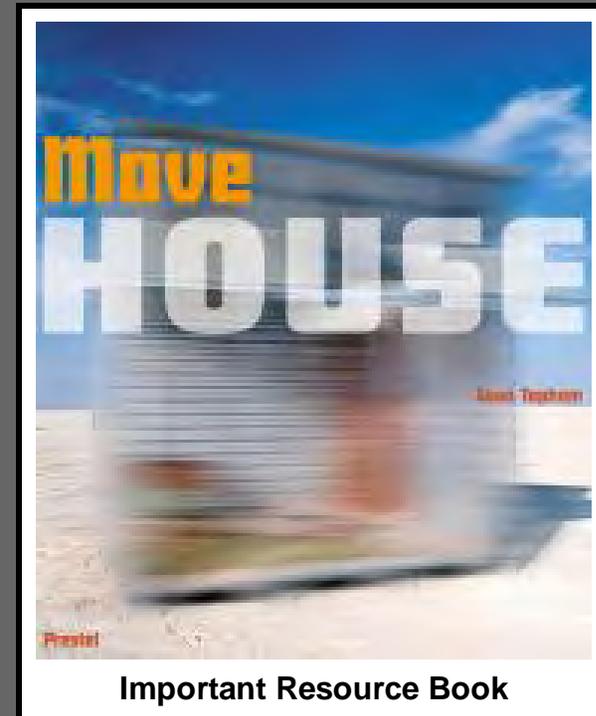
**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



This beautifully illustrated book is divided into four chapters that highlight and connect key attractions of mobile homes. Examples range from nomadic dwellings such as the teepee, yurt and Bedouin tent, to towable trailers with expandable features, to large modular structures such as Kisho Kurokawa's Nakagin Capsule Tower. Some illustrate shelters that apply to conditions where temporary dwellings are excluded by codes, and also where permanent structures are impractical. The book was published in 2004 by Prestel Publishing, 900 Broadway, Suite 603, New York, NY 10003 ([www.prestel.com](http://www.prestel.com))

Sean Topham



Key References

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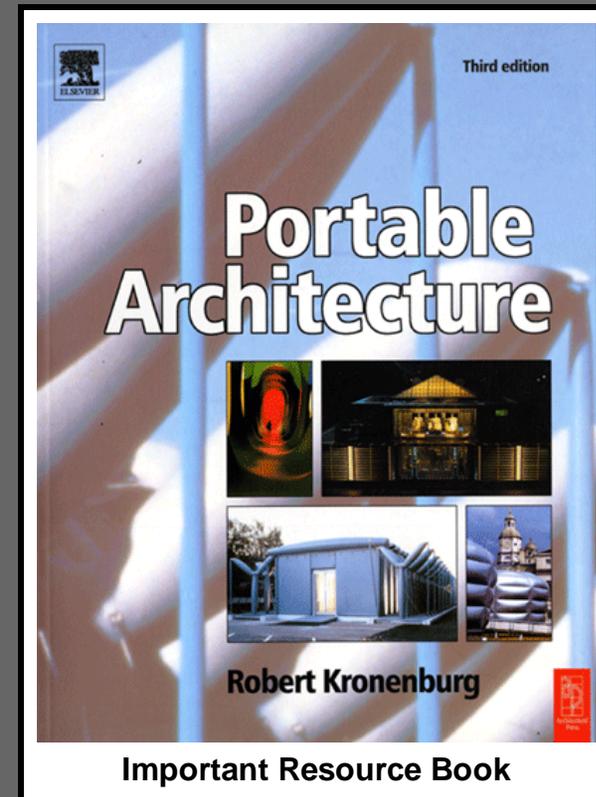
**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



Although portable shelters have been used from the earliest times humans began to build, it is only quite recently that some have come to be perceived as “real” architecture. “*Portable Architecture*” examines contemporary examples and explores the constructional and functional diversity of possibilities. The book is published as part of the Butterworth-Architectural Press New Technology series, Butterworth-Heinemann, Linacre House, Jordin Hill, Oxford ox2 8DP, and the third edition printing became available in 2003

Robert Kronenburg



Key References

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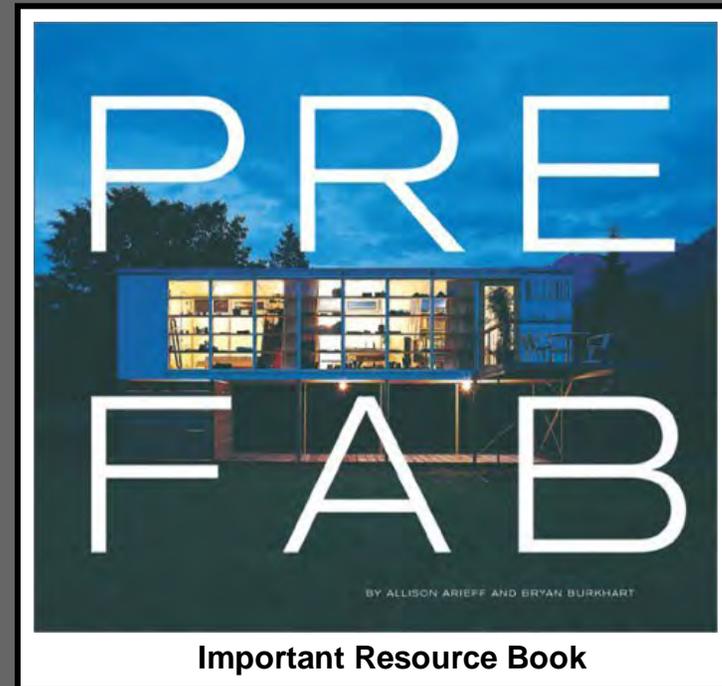
**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



“*Prefab*” discusses and illustrates the work of more than twenty-five contemporary architects and designers who are exploring myriad possibilities that prefabrication offers for future housing. These projects range from poetic constructions of Shigeru Ban to industrial minimalism of KFN’s portable structures, and from fantastic digitized aluminum prototypes of Greg Lynn to the stylish functionality of IKEA’s prefab apartments. The book was published in 2002 by Gibbs Smith, P.O. Box 667, Layton, Utah 04041 (see [www.gibbs-smith.com](http://www.gibbs-smith.com)).

Allison Arieff and Bryan Burkardt



Key References

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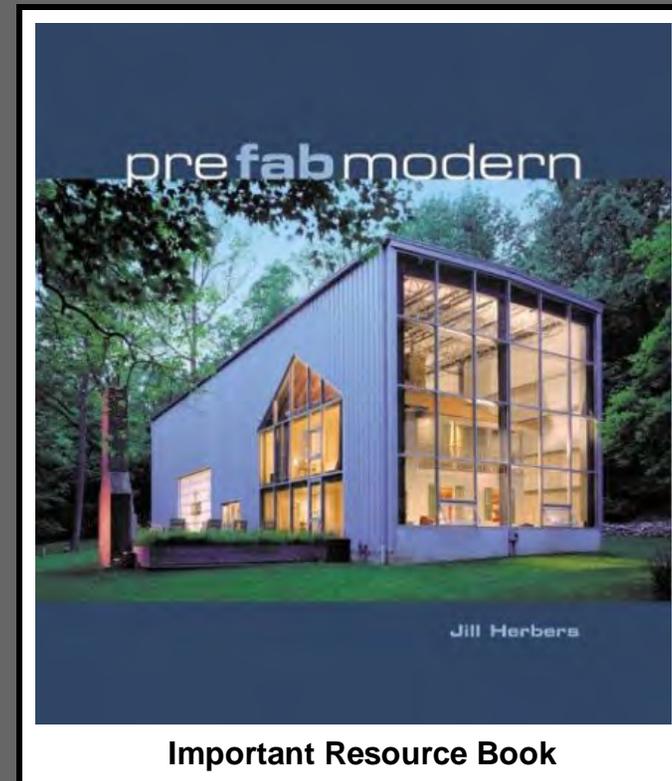
**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



“*Prefab Modern*” presents a wide array of affordable and distinctive prefab alternatives to conventional houses that are available along with homebuyer considerations in selecting various options. The book contains excellent photographs and illustrations, and discusses ways to avoid common pitfalls of custom construction while achieving a distinctive and attractive result. It also outlines historical origins of prefab developments and provides extensive up-to-date information and contact references. The book was published in 2004 by Harper Design International, and is distributed world-wide by Harper Collins International, 10 East 53<sup>rd</sup> Street, New York, NY 10022 ([www.harpercollins.com](http://www.harpercollins.com)).

Jill Herbers



**Important Resource Book**

Key References

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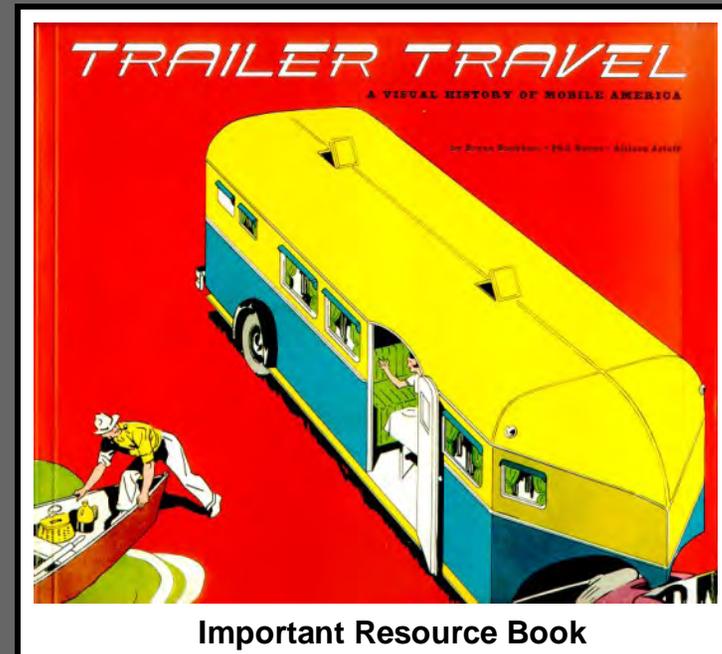
**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



“Travel Trailer” presents a visual history of America’s fascination with life on the road with numerous illustrations that begin with the early 1900s. It reveals many innovations that took place in trailer design over the years, and a wide variety of manufactured types. The book was originally published in 2002 by Gibbs Smith, P.O. Box 667, Layton, Utah and can be obtained by contacting [www.gibbs-smith.com](http://www.gibbs-smith.com).

Bryan Burkardt and Allison Arieff



Key References

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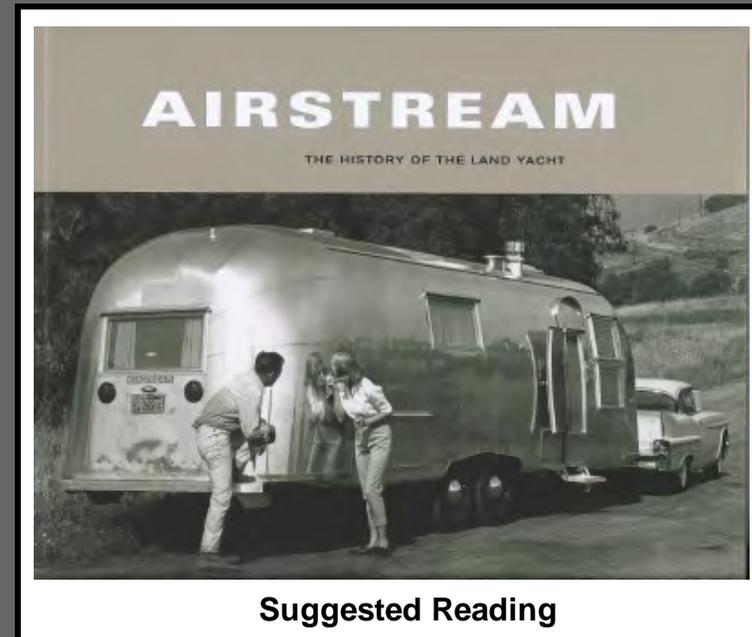
**SHELTER DESIGN AND CONSTRUCTION**

**PREFACE**



This book presents an illustrated chronicle of a development in mobile habitation that set a nation of travelers in motion and started a movement in living patterns that continues to this day. The history of the “land yacht” documents the trailer’s important influences on design as more than just a product. It is also the precursor for a shelter type that addresses both temporary and permanent housing needs for people of ranging incomes. Copyrighted in 2000, the book is published by Chronicle Books LLC, San Francisco, CA 94105, [www.chroniclebooks.com](http://www.chroniclebooks.com).

Bryan Burkardt and David Hunt



**Suggested Reading**

Supporting Materials

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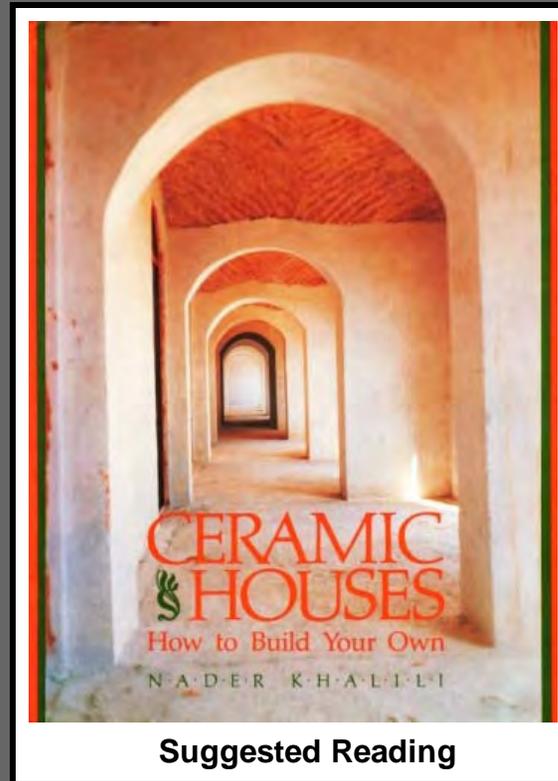
**SHELTER DESIGN AND CONSTRUCTION**

**SPECIAL CREDITS**



Nader Khalili, the author of this book, is an architect with great experience and knowledge regarding shelter construction using simple materials available to all: earth, water, air and fire. “*Ceramic Houses*” discusses historic ways fundamental lessons have been applied by desert people in Iran and Toas, New Mexico, and philosophical and design principles that are equally valid today. Materials and techniques for fired-earth mixtures, forms, block-making and construction are explained and illustrated. The book was first published in 1986 by Harper & Row Publishers Inc., 10 East 53 Street, New York, NY 10022.

Nader Khalili



**Suggested Reading**

Supporting Materials

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**SHELTER DESIGN AND CONSTRUCTION**

**SPECIAL CREDITS**



Transparency and luminescence have become important features of contemporary structures, most particularly as a result of an advancement of new material and construction technologies. This book presents thirty-three projects that exemplify this trend, including a broad range of building types, scales and approaches involving more than thirty architects. The photographs and drawn illustrations are excellent. The book was published in conjunction with the “*Light Construction*” exhibition in 1995, organized by Terence Riley, Chief Curator, Department of Architecture and Design at the Museum of Modern Art, New York, NY. It went into its fourth printing in 2003, and is being distributed by D.A.P/Distributed Art Publishers, Inc., New York, NY.

Terence Riley



Supporting Materials

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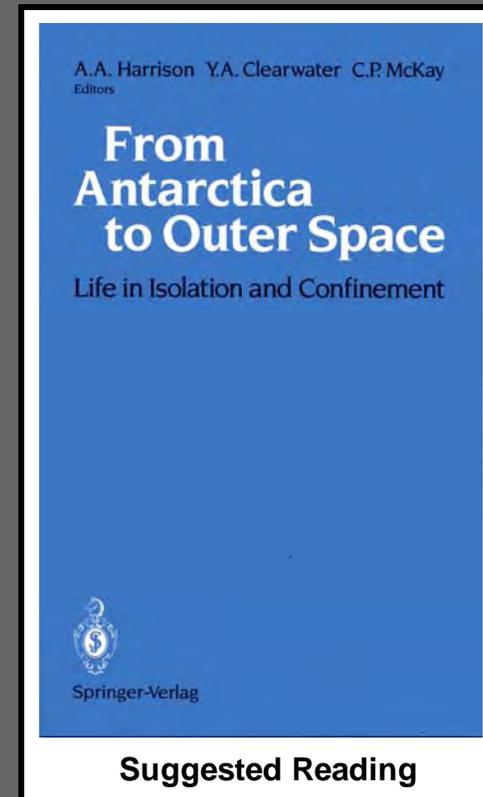
**SHELTER DESIGN AND CONSTRUCTION**

**SPECIAL CREDITS**



This book by Albert Harrison at the Department of Psychology, UC Davis Campus and Yvonne Clearwater at the Aerospace Human Factors Division, NASA-Ames Research Center and Christopher McKay, Space Science Division, NASA-Ames Research Center is based upon papers presented at a “*Human Experience in Antarctica: Applications to Life in Space*” conference in the late 1980s. It is highly recommended to readers who are interested in extreme environment analogs influencing habitat human factors design, and is published by Springer-Verlag New York, Inc., 175 Fifth Avenue, New York, NY 10010.

A. Harrison, Y. Clearwater  
and C. McKay



**Suggested Reading**

**Supporting Materials**

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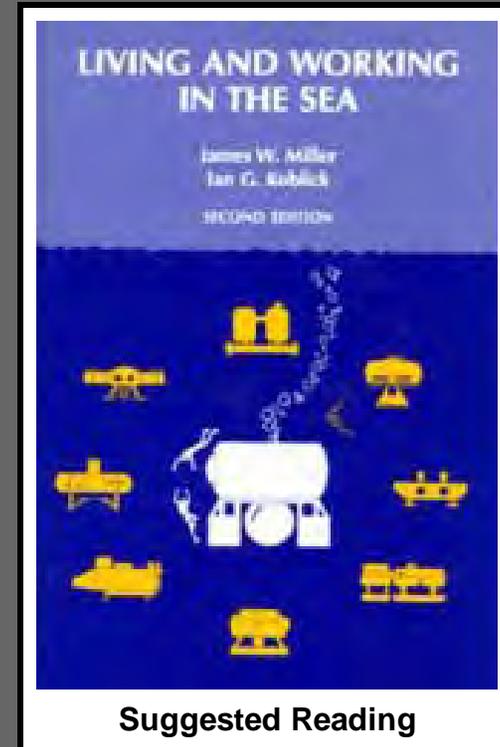
**SHELTER DESIGN AND CONSTRUCTION**

**SPECIAL CREDITS**



This book illuminates challenges, requirements and perils of undersea living and discusses how the development of saturation diving and seafloor technology has led to the creation of 65 different habitats. More than 200 photographs are presented along with many technical illustrations and personal accounts of aquanaut experiences. Topics include: food and water management; CO<sub>2</sub> / odor removal; communications, cooking and lighting; emergency facilities and procedures; medical and psychological issues; and operations. It was first published in 1984 by Van Nostrand Reinhold Company, Inc., 135 West 50<sup>th</sup> Street, New York, NY 10020.

James Miller and Ian Kublick



Supporting Materials

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**SHELTER DESIGN AND CONSTRUCTION**

**SPECIAL CREDITS**



For chapters A, B, C of this report please go to the "Shelter Design and Construction. Part I".

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# SECTION A : BACKGROUND

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The term “shelter” is generally defined as something that provides humans and equipment with security and protection from weather.

- Their special designs respond to a variety of needs and conditions, including:
  - Habitats in harsh, remote settings.
  - Refugees from natural and man-made disasters.
  - Economical housing, particularly for low-income populations.
  - Transportable, easily deployable accommodations for travel and periodic events.



Applications

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**BACKGROUND**

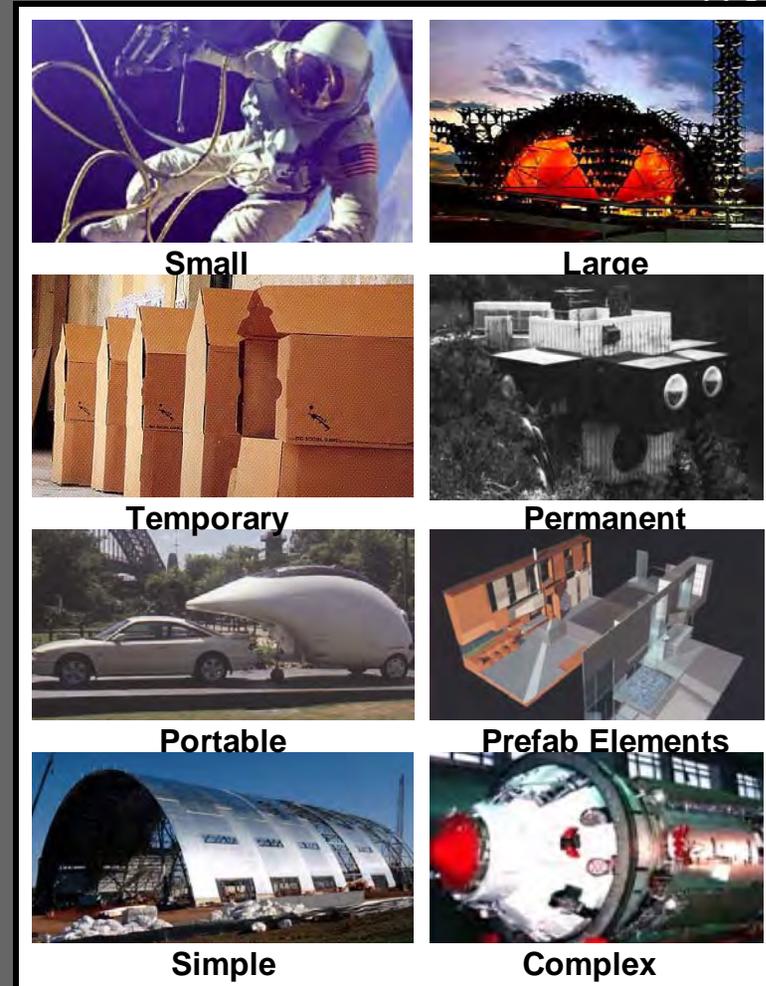
**THE NATURE OF SHELTERS**



Shelters are essential in all natural settings where humans reside.

- As applied in this presentation, the term shelter covers a broad variety of sizes, types and special features:

- They can be very small, such as an astronaut pressure suit, or very large such as a long-span space frame.
- They can be very temporary, constructed of cardboard, or permanent and substantial.
- They can be portable entities, or assembled from prefabricated elements.
- They can be simple, prefab structures, or complex, modular capsules.



Diversity

## BACKGROUND

## THE NATURE OF SHELTERS

Shelters have been designed and adapted to extreme environmental settings and conditions.

- Many of these locales are difficult to access, present harsh climates, and pose special construction challenges including:
  - Space orbital and planetary surface facilities.
  - Ocean surface and underwater habitats.
  - Polar research stations and construction/energy exploration sites.
  - Natural and man-made disaster refuges.



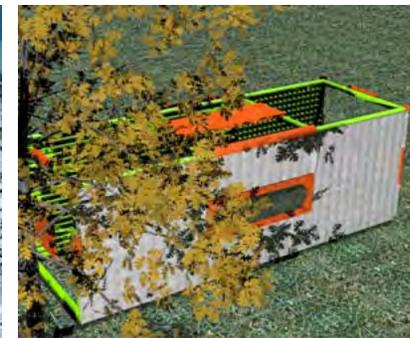
**Apollo Lunar Module**



**Submarine**



**Antarctic Station**



**SICSA Emergency Shelter**

**Settings**

## BACKGROUND

## THE NATURE OF SHELTERS



**Experiences on US and Russian spacecraft, underwater vessels, and polar stations have revealed a variety of common issues:**

- Cut off from “the outside”, crews must learn to be resourceful, and to depend upon one another:
  - They must work to help crewmates deal with mental and physical stresses.
  - They are required to adapt to a lack of familiar comfort and recreational amenities.
  - They must be prepared for fatiguing work overloads and stimuli deprivations.
  - They must be prepared to address equipment malfunctions that can jeopardize activities and lives.
- Common types of constraints place severe requirements and restrictions on habitat design and operations:
  - Limitations on internal volumes that can be delivered to support human activities.
  - Limitations on equipment, labor and processes for structure assembly/deployment.
  - Limitations on maintenance and repairs (people, tools/ spares and methods).
  - Safety and operations under harsh environmental conditions and demanding mission schedules.

**Common Extreme Environment Issues**

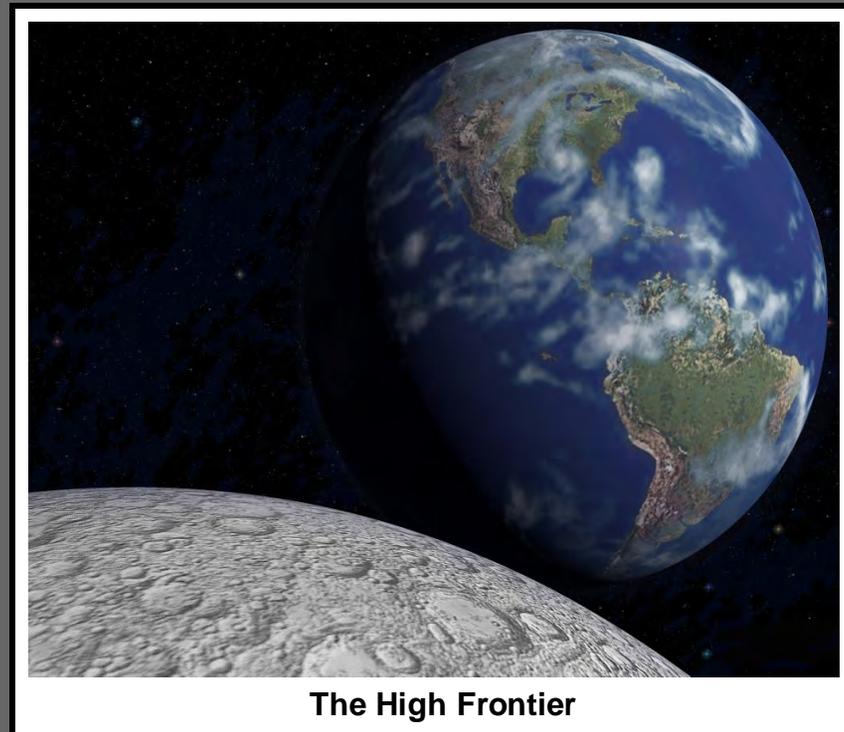
**BACKGROUND**

**THE NATURE OF SHELTERS**



Habitats in space must provide artificial environments to support life and maintain crew health and performance under extreme conditions.

- Space poses unique and challenging design problems, including:
  - Zero or reduced gravity conditions.
  - Long-term isolation in small spaces with very limited amenities.
  - Radiation and other health/safety hazards.
  - Severe launch payload restrictions upon allowable habitat size and mass.



**The High Frontier**

**Orbital and Planetary Surface Facilities**

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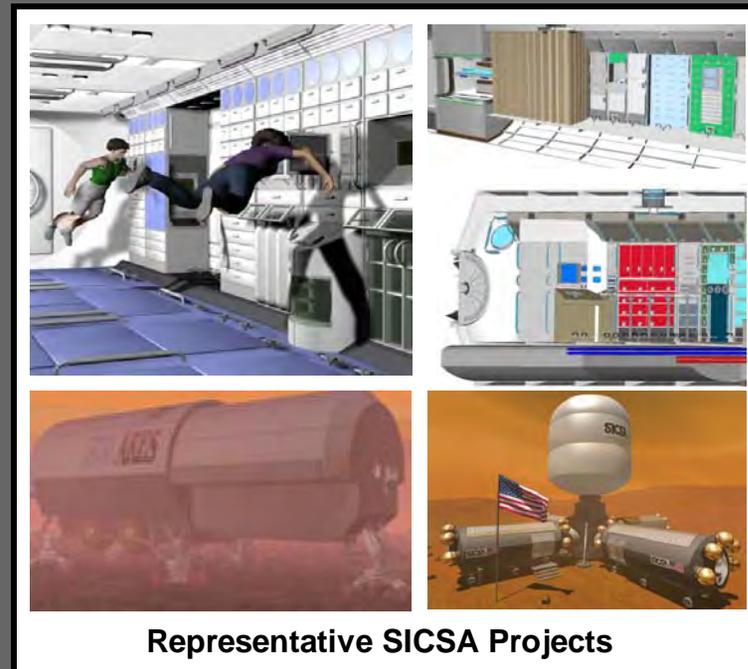
**BACKGROUND**

**THE NATURE OF SHELTERS**



SICSA has undertaken many space habitat planning and design projects.

- These and other habitat examples, along with a substantial amount of background information, can be found in Parts I, II, III, and IV of this Seminar Lecture Series, including:
  - Space Stations in Low Earth Orbit (LEO)
  - Orbital transfer vehicles (from LEO to Mars orbits)
  - Lunar surface modules
  - Mars surface modules



**Representative SICSA Projects**

**Orbital and Planetary Surface Facilities**

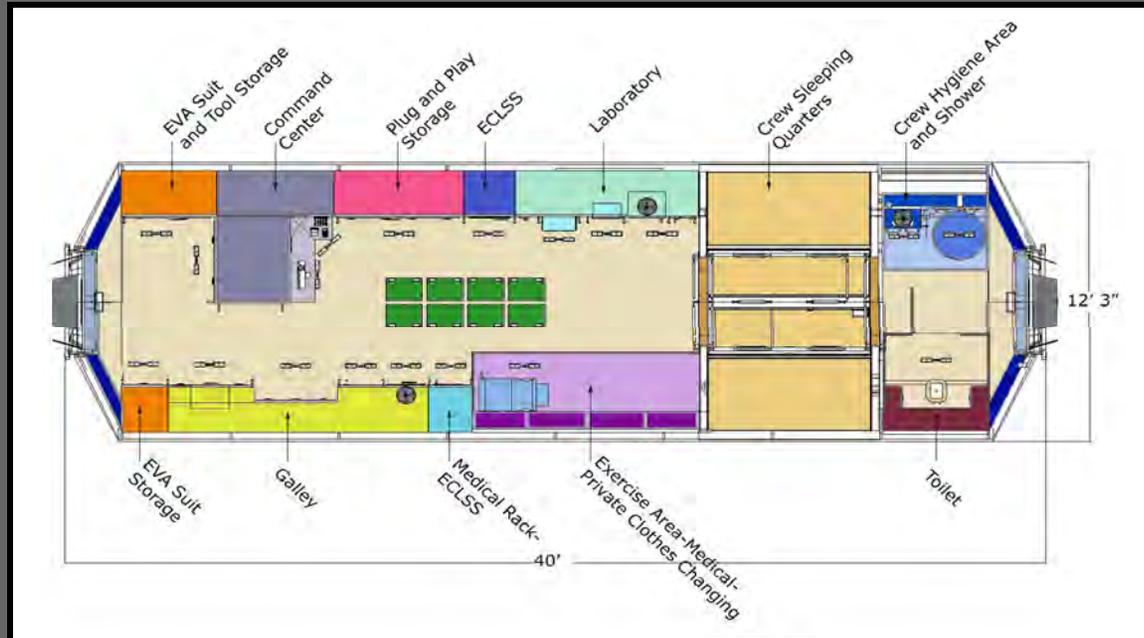
**BACKGROUND**

**THE NATURE OF SHELTERS**

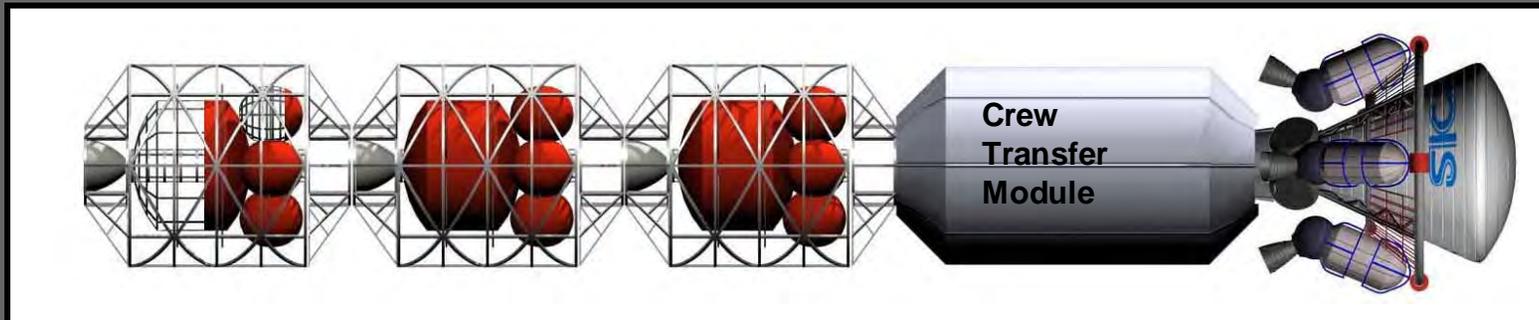


SICSA

A-8



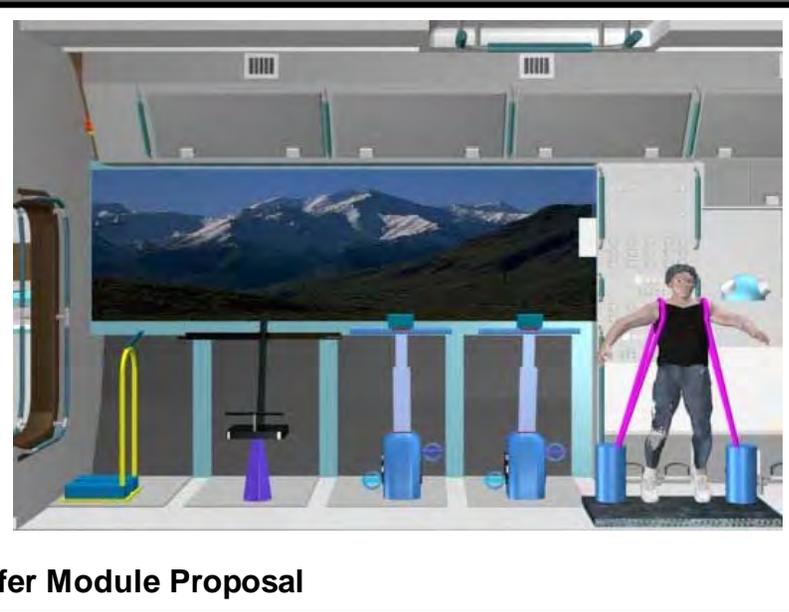
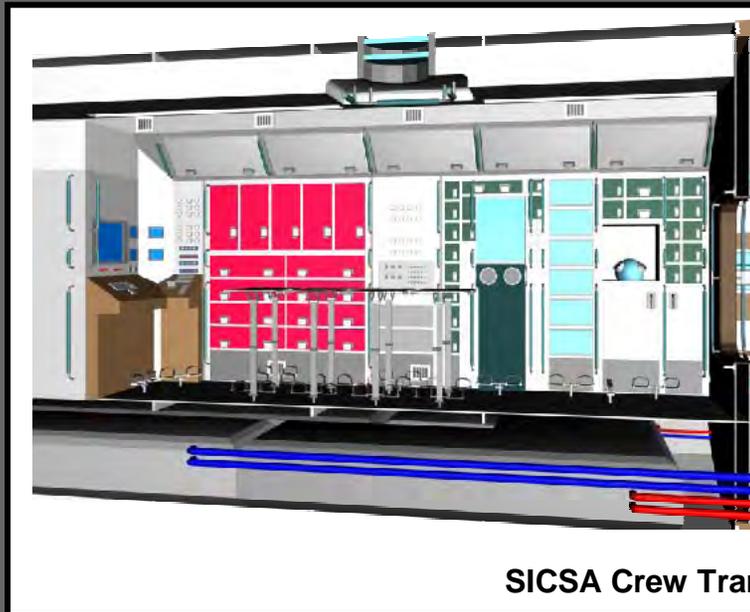
SICSA Crew Transfer Module Proposal



Orbital and Planetary Surface Facilities

BACKGROUND

THE NATURE OF SHELTERS



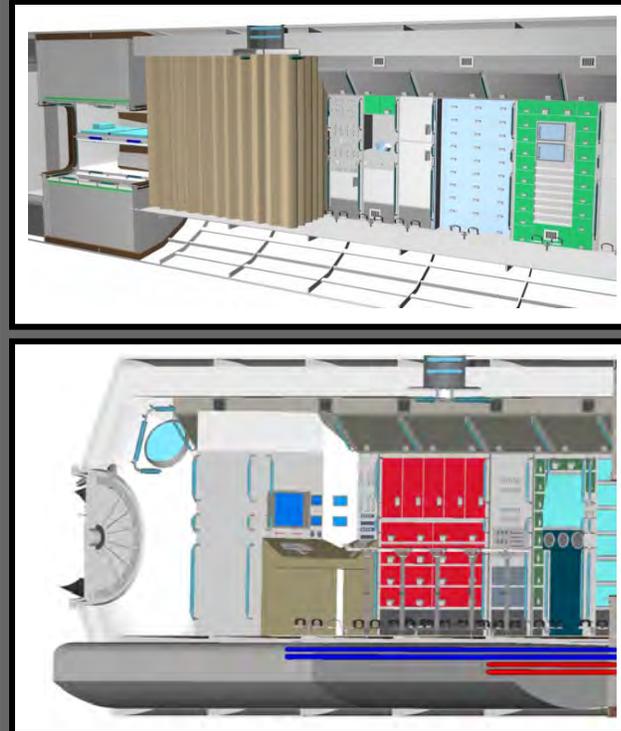
**SICSA Crew Transfer Module Proposal**

**Orbital and Planetary Surface Facilities**

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**BACKGROUND**

**THE NATURE OF SHELTERS**



Orbital and Planetary Surface Facilities

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**BACKGROUND**

**THE NATURE OF SHELTERS**



SICSA



**Hard and Inflatable Modules**



**SICSA Mars Proposal**

Orbital and Planetary Surface Facilities

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**BACKGROUND**

**THE NATURE OF SHELTERS**



Orbital and Planetary Surface Facilities

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**BACKGROUND**

**THE NATURE OF SHELTERS**



Orbital and Planetary Surface Facilities

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**BACKGROUND**

**THE NATURE OF SHELTERS**



**SICSA ARES Vehicle**



**Mars Transfer Hab Concept**

**Orbital and Planetary Surface Facilities**

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**BACKGROUND**

**THE NATURE OF SHELTERS**



Oceans that cover vast expanses of our planet's surface present opportunities and challenges for human habitation.

- These environments provide important venues for a variety of offshore facilities including:
  - Underwater marine research laboratories and hotel lodging.
  - Surface research stations and resorts.
  - Floating communities to expand living space in coastal locales.



**Ocean Environment**

**Ocean Surface and Underwater Habitats**

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**BACKGROUND**

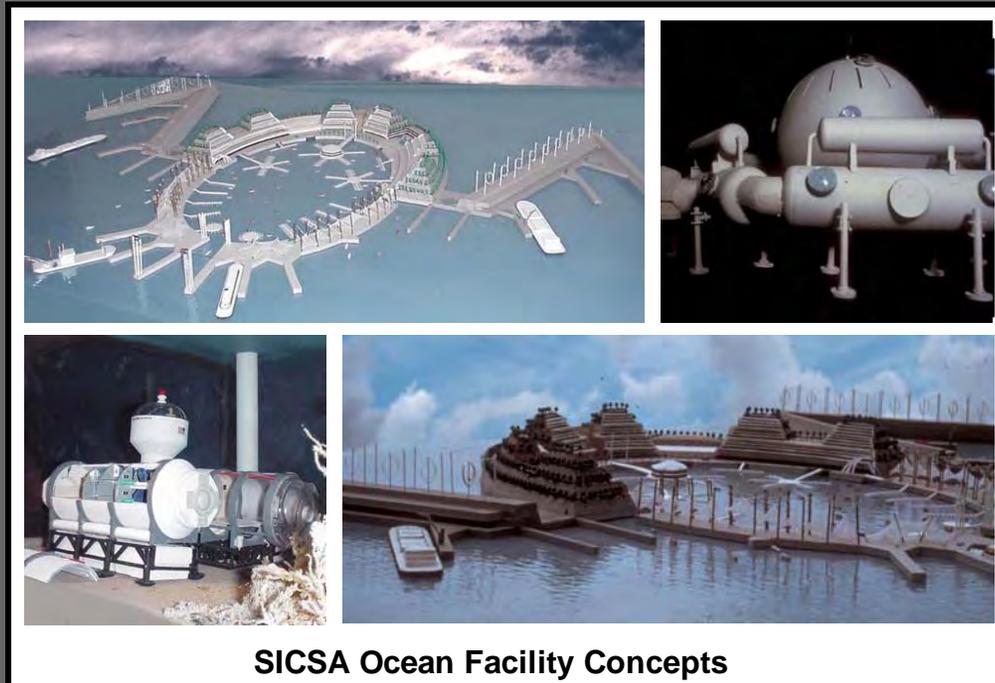
**THE NATURE OF SHELTERS**



Ocean habitats present many design requirements that are also common to space and other extreme environments.

- Important considerations in planning these facilities include transportation, safety, and ecological issues:
  - Transfers of structures and users to the locations of use under all types of weather conditions.
  - Safeguard features to protect habitats and users from hurricanes and tidal waves.
  - Access/ egress and control/ rescue for underwater diving operations.

SICSA

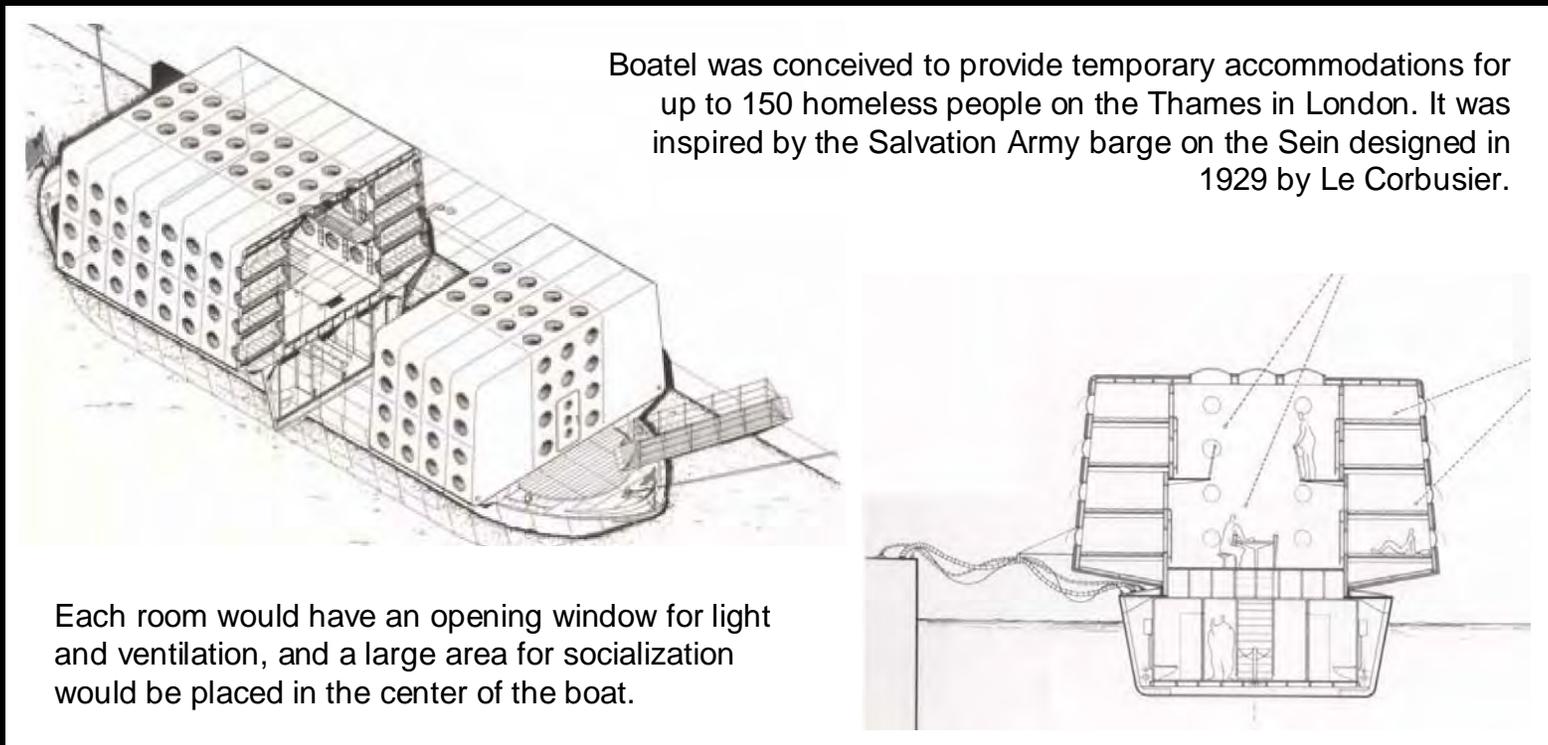


**SICSA Ocean Facility Concepts**

**Ocean Surface and Underwater Habitats**

**BACKGROUND**

**THE NATURE OF SHELTERS**



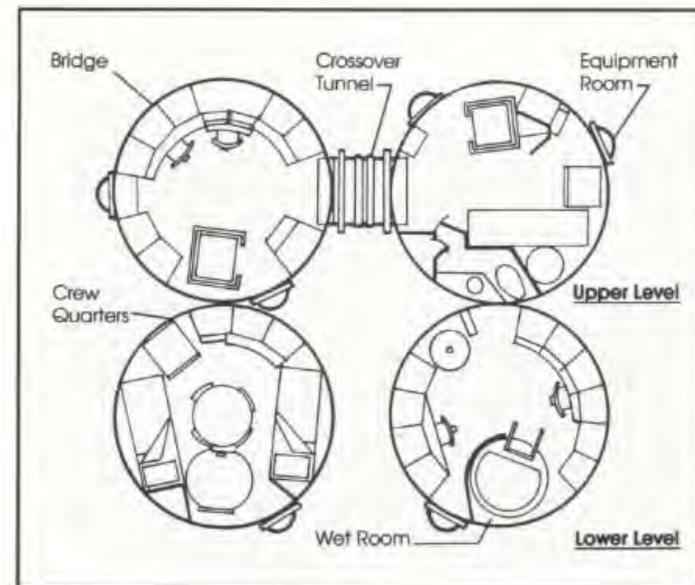
Ocean Surface and Underwater Habitats

BACKGROUND

THE NATURE OF SHELTERS

**Manned Life Support System Tests (1968-71):**  
McDonnell Douglas conducted 60 day (1968) and 90 day (1971) tests in which crews of four were enclosed in sealed cabins to test regenerative life support systems. Abilities of crews to maintain physiological and psychological health were evaluated.

**Tektite (1969-1970):**  
The US Office of Naval Research sponsored an experiment in which four crewmembers were housed in an undersea habitat for 60 days. A key purpose was to study small group behavior and effectiveness under stressful, isolated conditions.



**Underwater Tektite I and II Habitat**

Ocean Surface and Underwater Habitats



Confinement on submarines can provide behavioral data that is informative for planning prolonged space missions:

- A large quantity of psychological data has been collected since 1953 about human adaptation and performance under adverse and stressful conditions.
- Crew populations on modern US ballistic missile submarines are relatively large, typically about 140 officers and enlisted personnel, creating cramped living conditions.
- Crews however, are primarily young single men, who are likely to be more homogenous than future space voyagers.



**Nuclear Submarines as Analogs**

Ocean Surface and Underwater Habitats

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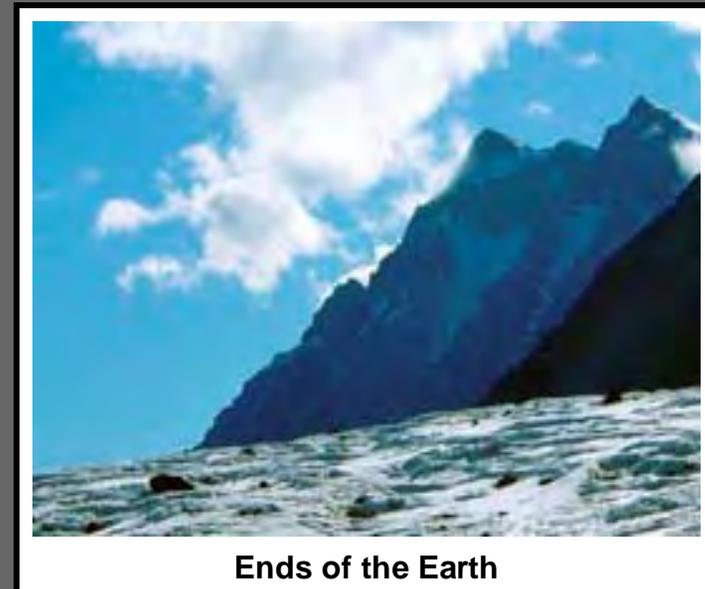
**BACKGROUND**

**THE NATURE OF SHELTERS**



Polar regions present extreme weather conditions and rugged terrain features that impose challenges.

- Wind, snow, frigid temperatures, ice movements, crevasses and even predators demand consideration in designing habitats such as:
  - Small insulated tents for explorers.
  - Modular and deployable accommodations for military and construction encampments.
  - Science research stations for government and private organizations.
  - Weather-monitoring and communication posts.
  - Training facilities and technology test beds for future planetary exploration.



**Ends of the Earth**

**Polar Facilities**

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**BACKGROUND**

**THE NATURE OF SHELTERS**



Buro Happold and Lifschutz Davidson presented a design for the Halley VI Antarctic Research Station competition that proposed linked space station-like modules on jackable legs to raise the structures above accumulated snow.

The concept provided for general community space along with quiet areas for living and leisure. “Trains” of modules attached end-to-end would be connected via elevated closed passageways to afford circulation throughout the complex.

**Buro Happold & Lifschutz Davidson**



**Halley VI Antarctic Research Station Concept**

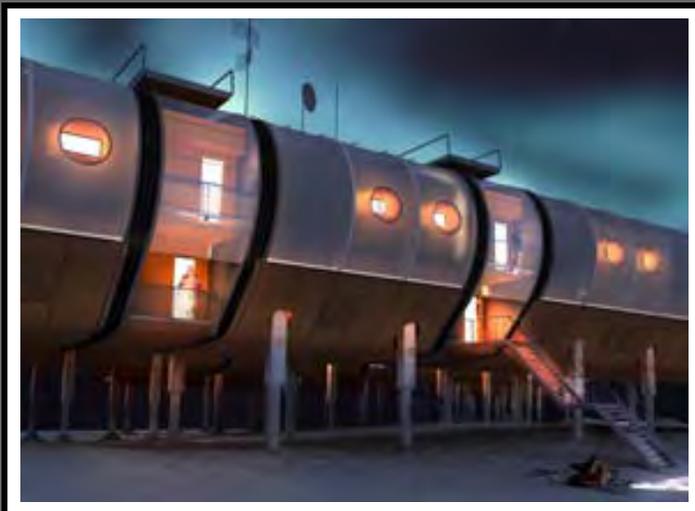
**Polar Facilities**

**BACKGROUND**

**THE NATURE OF SHELTERS**



The firm of Hopkins Architects, Ltd proposed a modular structure with hydraulic legs that would enable it to walk away from dangerous ice breakups. It also provided large windows for viewing the spectacular Southern Lights.



Hopkins Architects Ltd.



Halley VI Antarctic Research Station Concept

Polar Facilities

BACKGROUND

THE NATURE OF SHELTERS



Faber Munsell and Hugh Broughton Architects were selected as winners for a Halley VI Research Station design competition sponsored by the British Antarctic Survey (BAS).

- The proposed new complex is to be placed 10,000 miles from the UK on the Brunt Ice Shelf.
- Workspace and energy pods are grouped around a central “living module”.
- Modules are raised on legs to accommodate about 105 m/year of snow accumulation.
- Skis on the legs enable the 12 modules to be towed for relocation away from the sea ice edge.
- Each leg can be raised to enable snow to be placed underneath to periodically lift the modules.
- Modules are projected to weight between 65-130 tons each, and together house 52 people.
- Amenities include a hydrotherapy bath, sauna, gym, pool and greenhouse for growing vegetables.

A-23

Faber Munshell/  
Hugh Broughton Architects



**Halley VI Antarctic Research Station Concept**

**Polar Facilities**

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**BACKGROUND**

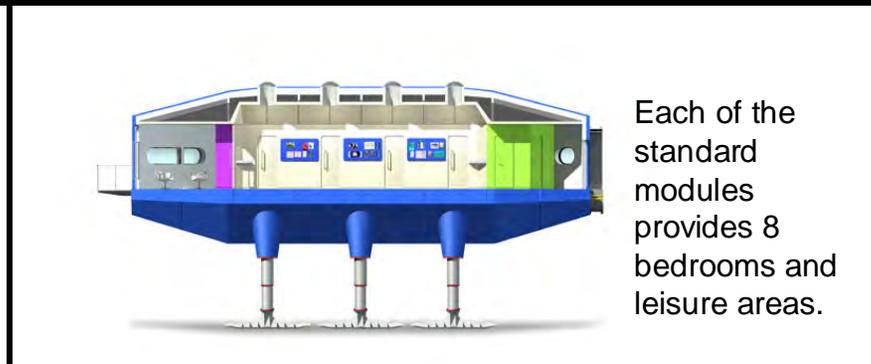
**THE NATURE OF SHELTERS**



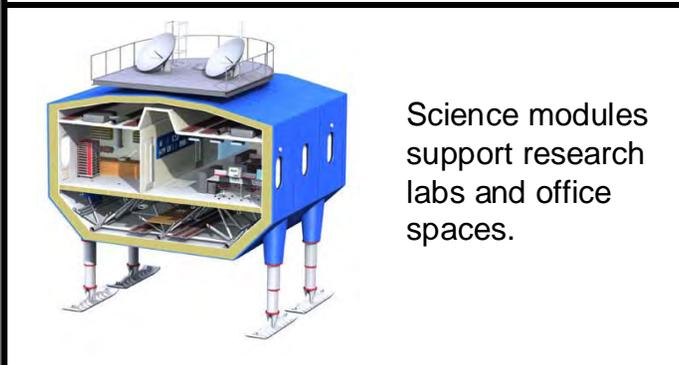
Faber Munshell/  
Hugh Broughton Architects



Mechanical legs on skis enable the modules to be raised and moved.



Each of the standard modules provides 8 bedrooms and leisure areas.



Science modules support research labs and office spaces.



A central module provides dining and recreation amenities.

Halley VI Antarctic Research Station Concept  
Polar Facilities

BACKGROUND

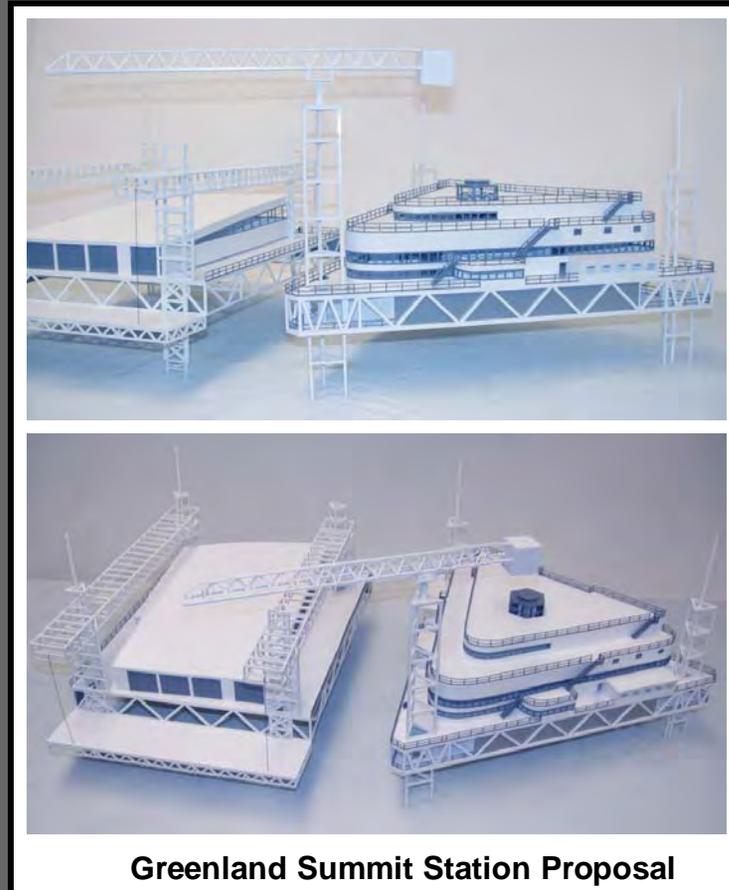
THE NATURE OF SHELTERS



SICSA

During 2004-2005, SICSA developed a design proposal for a facility to replace the current Summit Station in Greenland that was presented to the US National Science Foundation.

- The development was planned to support up to 50 people during the summer season, and 25 during winter. Features include:
  - Crew support accommodations such as: living quarters, a kitchen/ cafeteria, exercise/ toilet/ shower equipment, and a small health maintenance facility.
  - Work areas providing research labs, storage and maintenance spaces, and a greenhouse for hydroponics.
  - Jack-up structures to periodically raise the two buildings above annual snow accumulations.



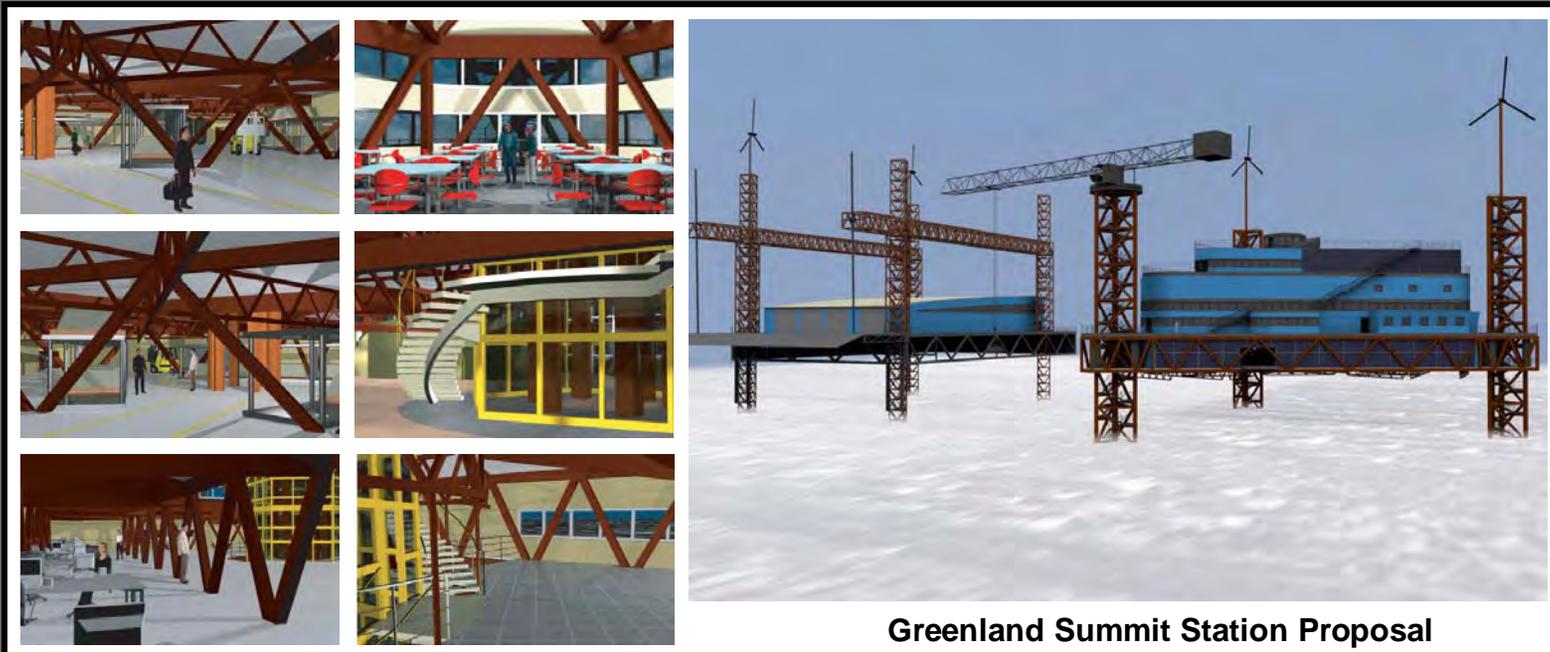
**Greenland Summit Station Proposal**

**Polar Facilities**

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**BACKGROUND**

**THE NATURE OF SHELTERS**



Polar Facilities

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**BACKGROUND**

**THE NATURE OF SHELTERS**



The facility shape was designed to minimize snow drift accumulations in its wind wake. The design was tested in a wind tunnel at the Applied Computing and Mechanics Laboratory (IMAC) in Lausanne, Switzerland, and also by placing a scale mockup of the structure at the Greenland Site.



**Snow Drift Test Mockup at Site**



**Greenland Summit Station Proposal**

**Polar Facilities**

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**BACKGROUND**

**THE NATURE OF SHELTERS**



Small Antarctic research stations, such as the 20-person US South Pole facility, present conditions which are similar in many respects to those that will be encountered on future lunar and planetary surface missions:

- Teams of highly motivated and trained personnel must learn to live and work together under remote, dark and hazardous conditions.
- Monitoring of crew adaptation and performance influences under analogous circumstances can yield important lessons.



**Small Antarctic Stations as Analogs**

Polar Facilities

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**BACKGROUND**

**THE NATURE OF SHELTERS**



SICSA has prepared design proposals for planetary surface training and technology testing facilities to be located in dry valleys of Antarctica. The plans would utilize a combination of space station-sized modules and larger inflatable greenhouse/ lab structures similar to those which might be used in space.

SICSA



**SICSA Antarctic Planetary Testbed Proposals**

**Polar Facilities**

**BACKGROUND**

**THE NATURE OF SHELTERS**



Having no home, either as an owner or tenant, is a devastating experience known by large populations throughout the world.

- Homelessness exposes people to a variety of tragic and traumatic circumstances:
  - When triggered by a personal, natural or man-made disaster, loss of home simultaneously entails a loss of social status associated with poverty.
  - Homeless people are exposed unprotected both from climate, weather and social threats.
  - Absent available government-provided accommodations, displaced and disenfranchised people most often pursue desperate make-shift shelter expediencies.



**Earth and Human Disasters**

**Emergency Shelters**

**BACKGROUND**

**THE NATURE OF SHELTERS**



A wide variety of shelter proposals and manufactured systems which might be applied for emergency uses are presented later in this Part of the SICSA Seminar Series.

- Some recent concepts developed by SICSA, are offered as examples:
  - AirHab is a pneumatic inflatable approach emphasizing compact, lightweight construction and rapid deployment.
  - The DREAHM unit combines a modular container with integrated equipment and utilities with pneumatic bladder extension enclosures.
  - HOME features an articulating cargo structure with exterior wall panels that affords multiple configuration options.
  - Life Cube is a modular shelter constructed of articulating panels and plug-in utility units.

SICSA



Emergency Shelters

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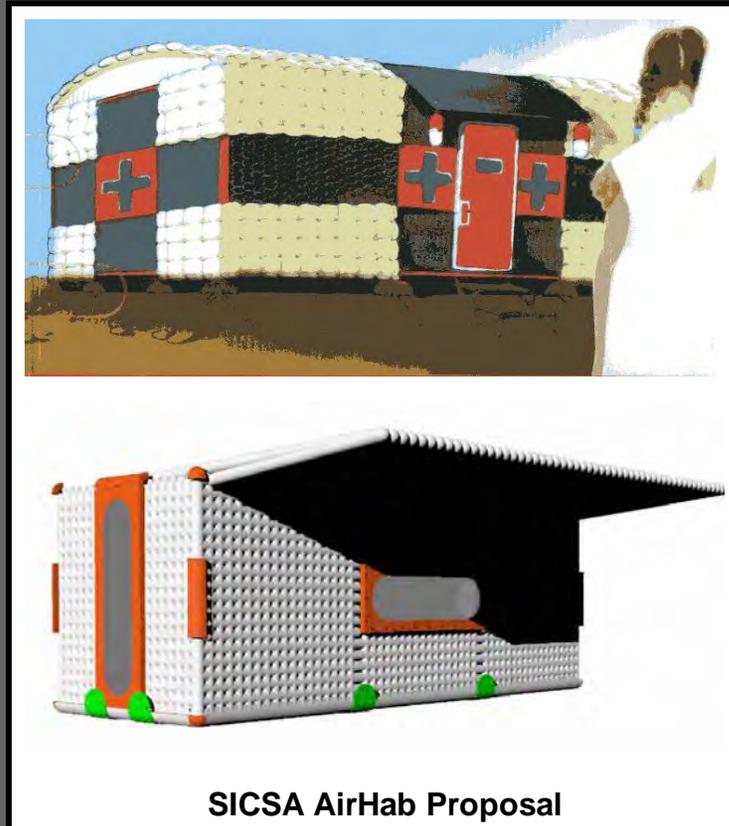
**BACKGROUND**
**THE NATURE OF SHELTERS**



SICSA's proposed AirHab concept features ultra-lightweight construction and rapid deployment without tools.

- The module walls and roof are comprised of air bladders that are inflated by a small battery-powered or manual pump:
  - The shipping container is folded out at the site to create a floor structure with pre-integrated electrical lines and plumbing interfaces.
  - Two different roof options are suggested, one using an arched form, and the other flat with an inflatable canopy.

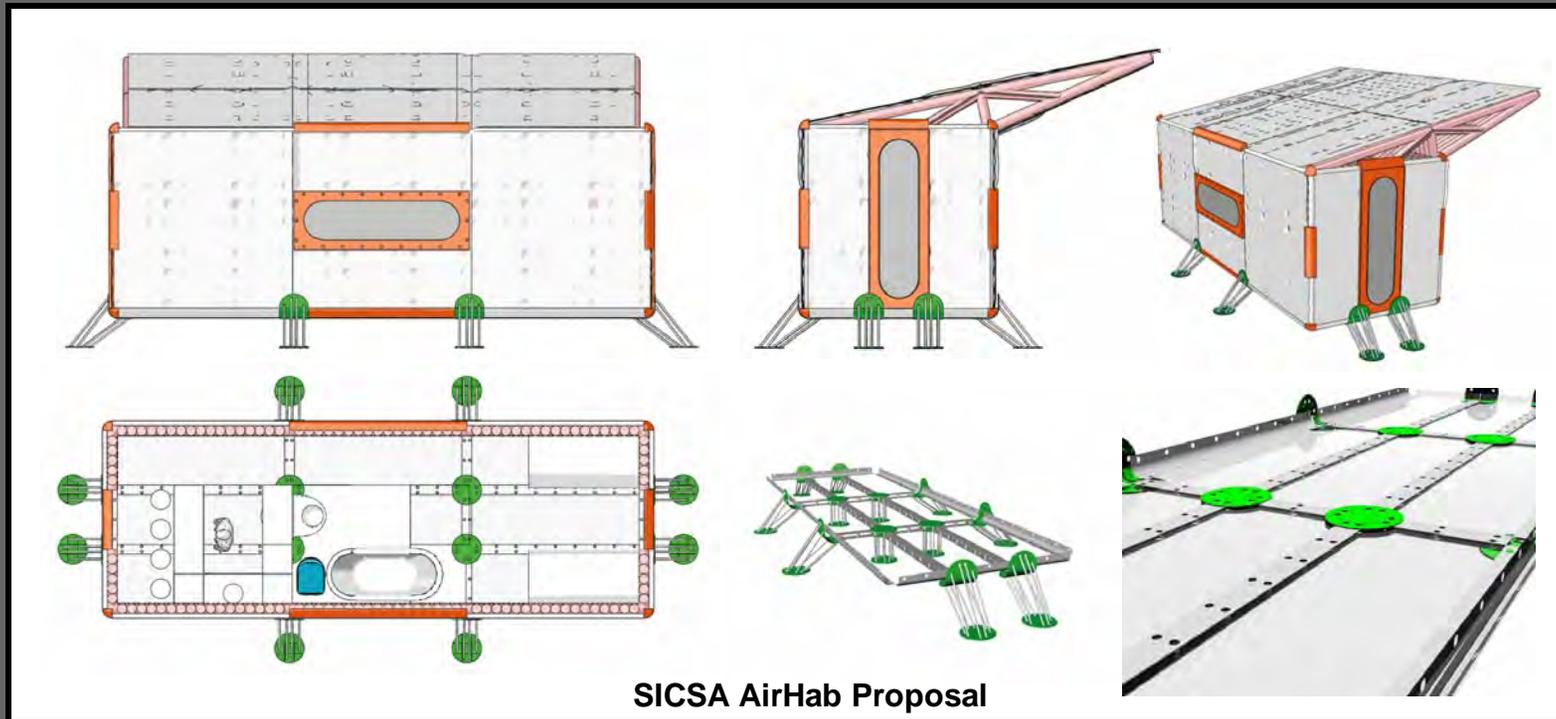
SICSA



Emergency Shelters

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**BACKGROUND****THE NATURE OF SHELTERS**



Emergency Shelters

BACKGROUND

THE NATURE OF SHELTERS



SICSA's proposed Disaster Relief Emergency Assistance Habitation Module (DREAHM) unit can be transported by truck in a standard small 8 ft x 8 ft x 5 ft shipping container and rapidly deployed.

- Container sides pivot down to provide floor decks which support three enclosed extensions and an entry porch.



**Deployable/ Inflatable Canopy**

SICSA

A-34



**SICSA DREAHM Unit**

**Emergency Shelters**

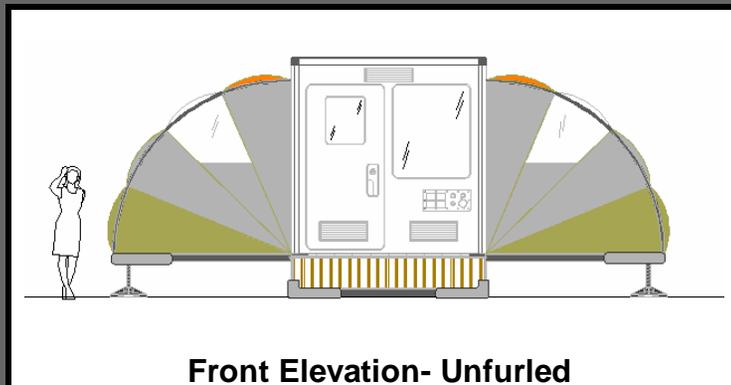
**BACKGROUND**

**THE NATURE OF SHELTERS**

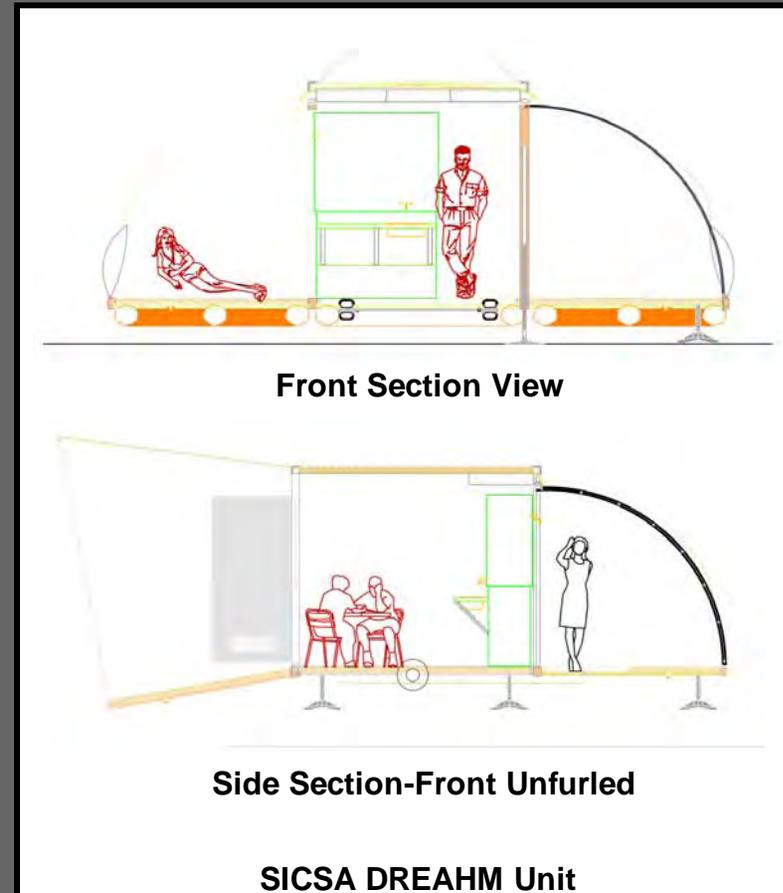


When deployed, the DREAHM unit provides 368 ft<sup>2</sup> of floor area and a 480 ft<sup>3</sup> volume to accommodate sleeping, a laboratory/ toilet/ shower, and a kitchen/ galley.

- The deployable canopies are stiffened by airbladders, and the core roof incorporates solar panels for electrical power.



Front Elevation- Unfurled



Front Section View

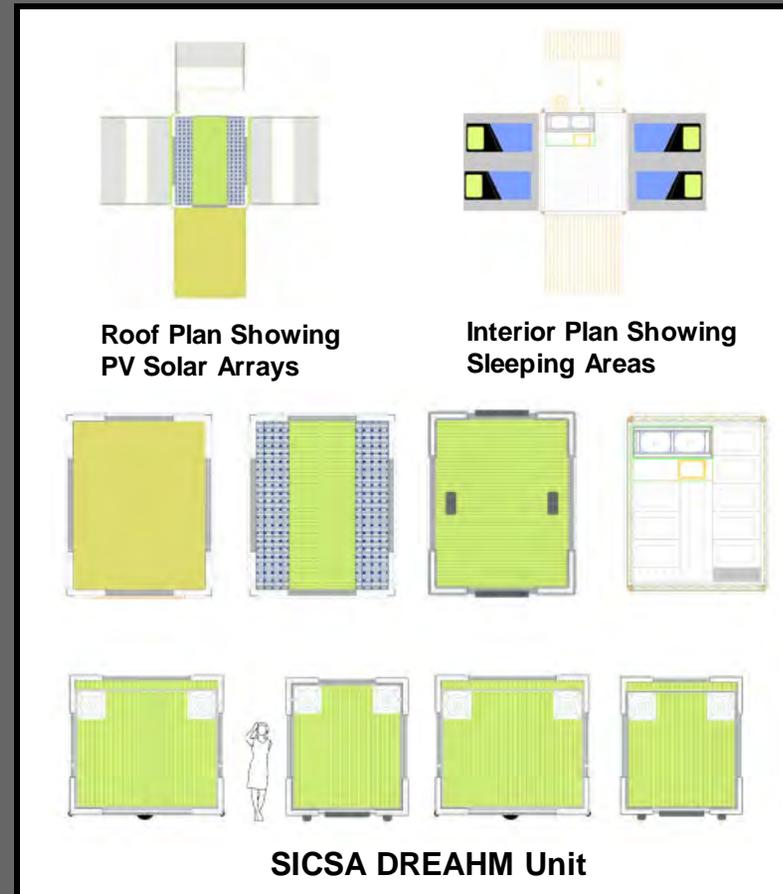
Side Section-Front Unfurled

SICSA DREAHM Unit

Emergency Shelters



Units can be clustered together in different patterns, and numbers and can be grouped to create a covered causeway.



Emergency Shelters

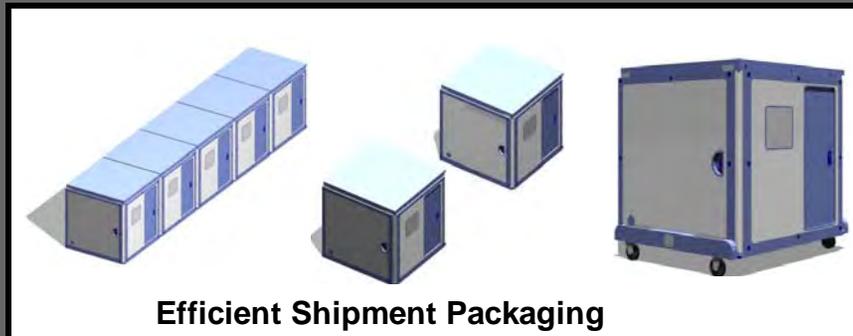
BACKGROUND

THE NATURE OF SHELTERS



SICSA's proposed HOME units are modular habitats comprised of articulating frames and panels that incorporate cooking, toilet and other equipment in the packages.

- Several packaged units can be transported by ship, rail, or truck in a long standard container volume:
  - Following deployment, the individual shelter units can be attached together to create larger interior spaces.
  - Two or more units can be joined back-to-back and/ or side-to-side for variable groupings.



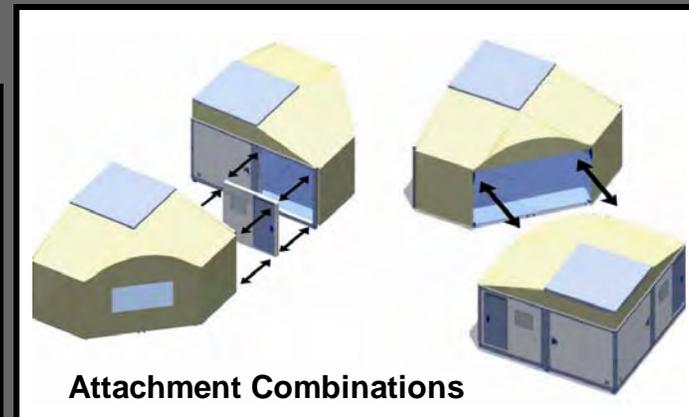
**Efficient Shipment Packaging**

SICSA

A-37



**SICSA HOME Proposal**



**Attachment Combinations**

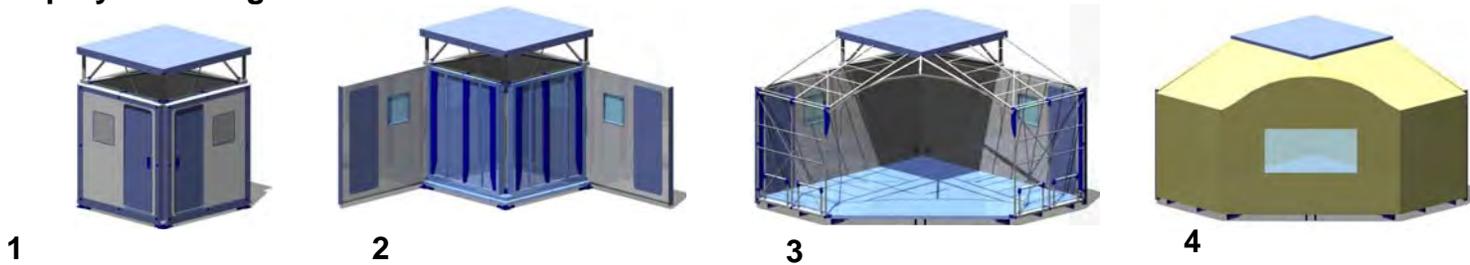
**Emergency Shelters**

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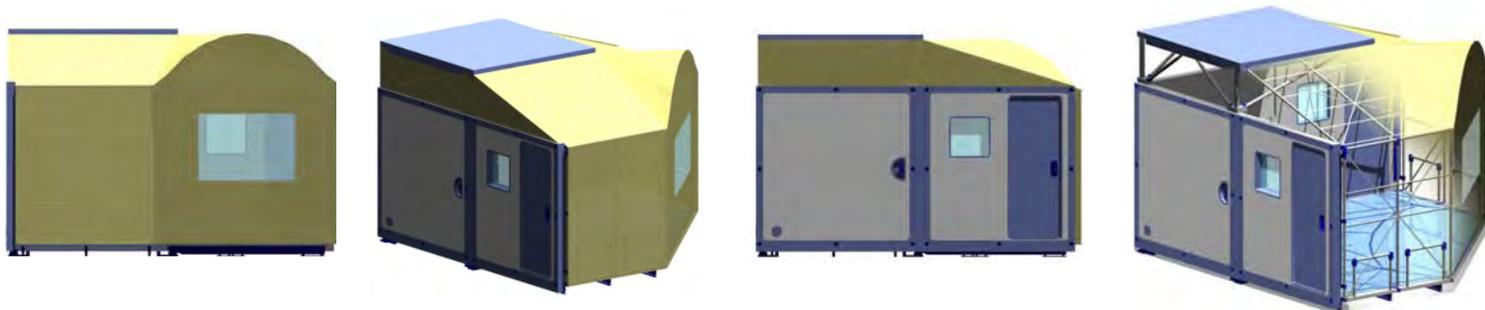
**BACKGROUND**

**THE NATURE OF SHELTERS**

**Deployment Stages**



**Exterior Deployed Views**



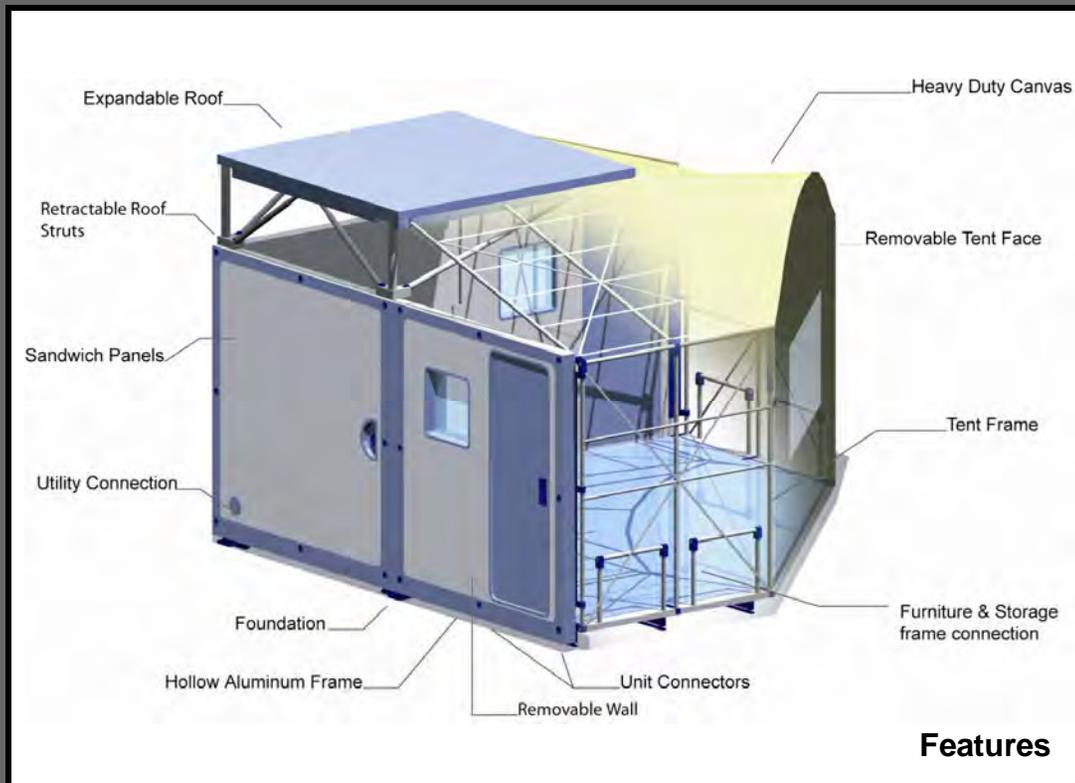
**SICSA HOME Proposal**

**Emergency Shelters**

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**BACKGROUND**

**THE NATURE OF SHELTERS**





Units come shipped with all interior components ready to assemble. Bunks, couches and storage units are stowed and deployed.



**SICSA HOME Proposal**

**Emergency Shelters**

**BACKGROUND**

**THE NATURE OF SHELTERS**

SICSA's proposed Life Cube can be shipped by air, rail and truck in a standard cargo container.

- The units are assembled at the site by folding out floor and roof panels, and then attaching end or side utility units with integrated cooking, toilet and furnishings:
  - Life Cube can be easily and rapidly deployed by untrained personnel.
  - Thermal insulation is incorporated for hot and cold environments.
  - The units can be installed on rocky/ uneven surfaces with little or no site preparation.
  - Hard wall construction enables security for occupants and their possessions.

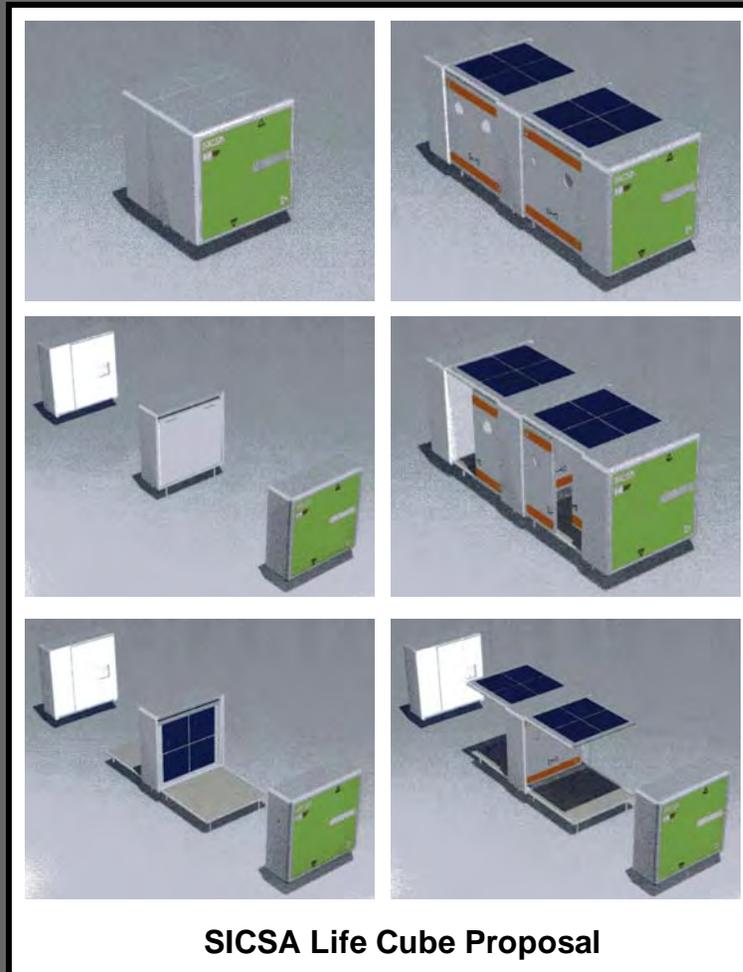


**SICSA Life Cube Proposal**

**Emergency Shelters**

**BACKGROUND**

**THE NATURE OF SHELTERS**

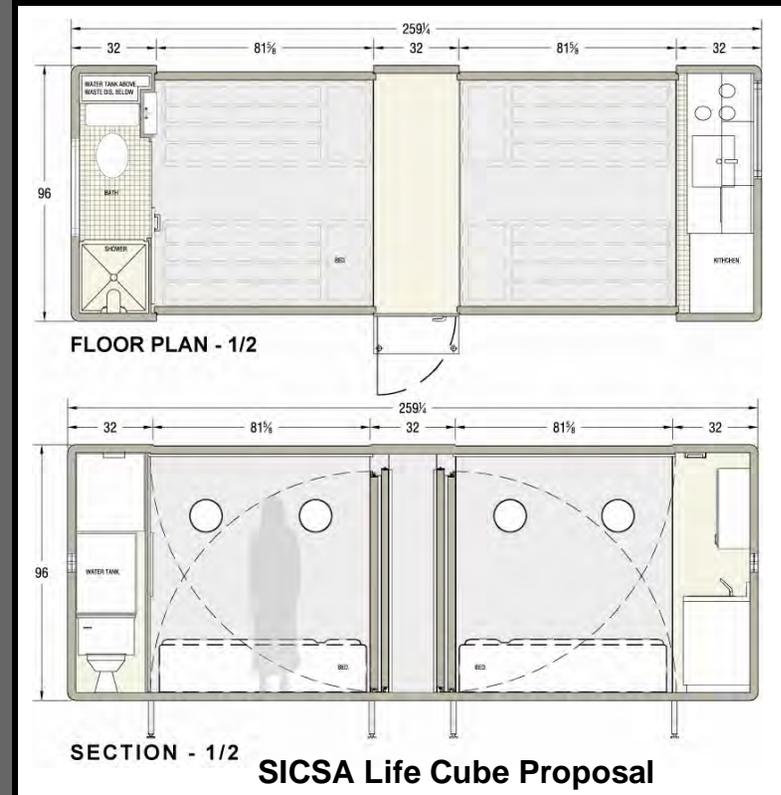
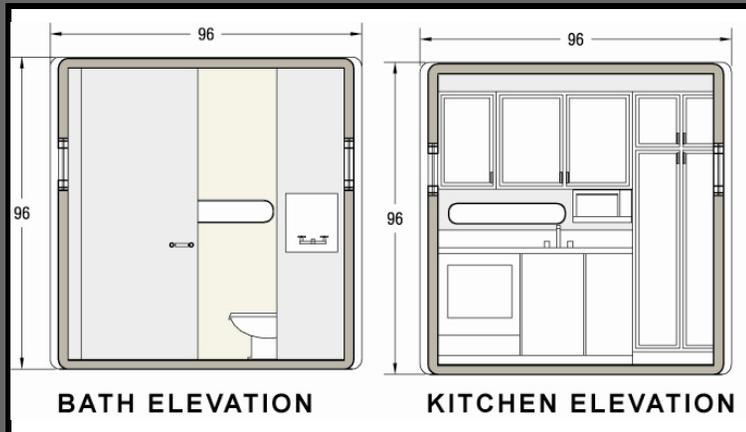
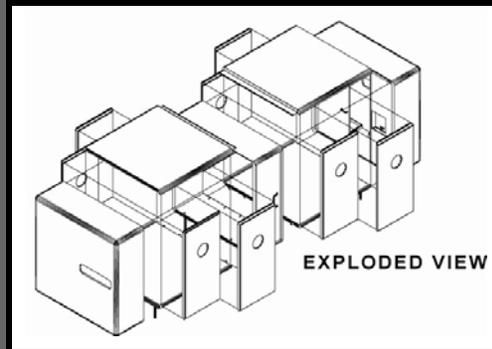


**SICSA Life Cube Proposal**

**Emergency Shelters**

**BACKGROUND**

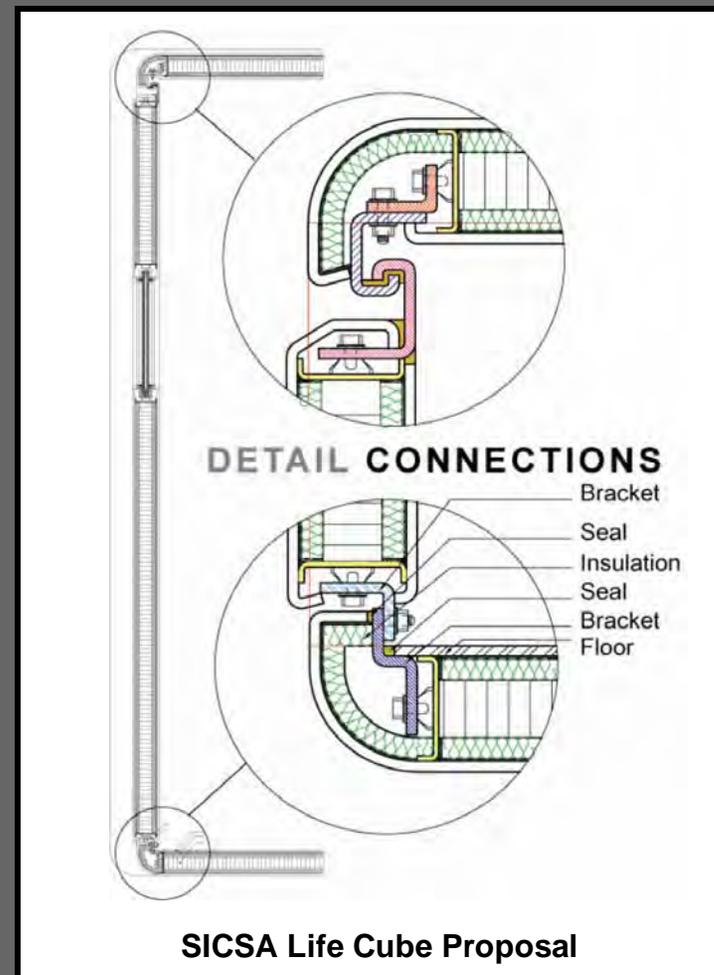
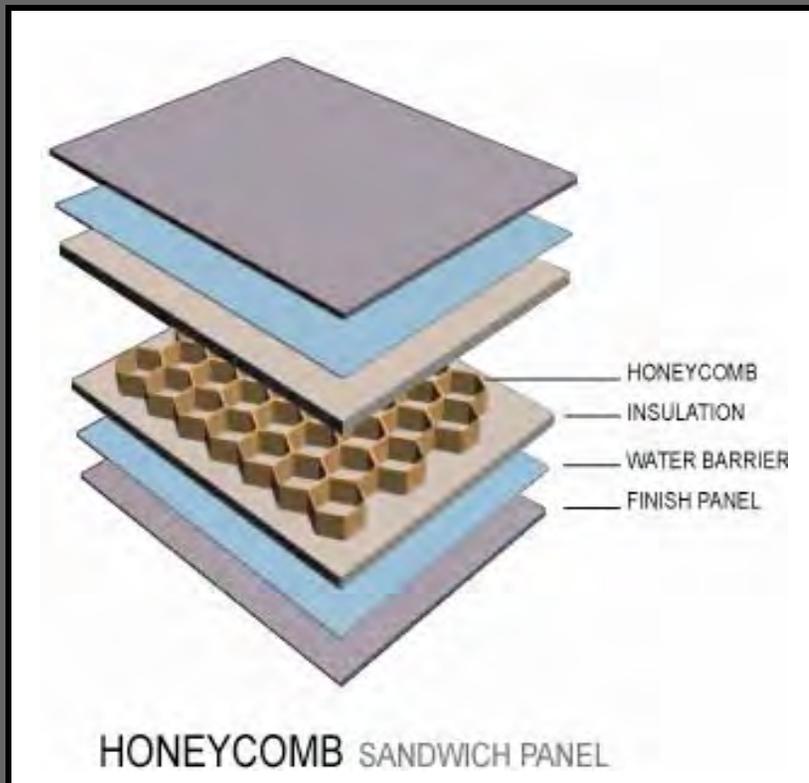
**THE NATURE OF SHELTERS**



Emergency Shelters

BACKGROUND

THE NATURE OF SHELTERS



Emergency Shelters

BACKGROUND

THE NATURE OF SHELTERS



**Multiple-Unit Option**



**SICSA Life Cube Proposal**

Emergency Shelters

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**BACKGROUND**

**THE NATURE OF SHELTERS**

Human survival has always depended upon abilities to adapt shelters to different environmental settings:

- Transportable tents carried by desert nomads.
- Tepees constructed by early Native Americans.
- Ice igloos built by northern latitude Inuits.
- Sod houses excavated by North American prairie settlers.
- Log and stone cabins constructed using local materials.
- Prairie Schooner covered wagons used by pioneers of the American West.



**Yurt**



**Tepee**



**Igloo**



**Sod House**



**Log Cabin**



**Prairie Schooner**

**Historic Precedents**

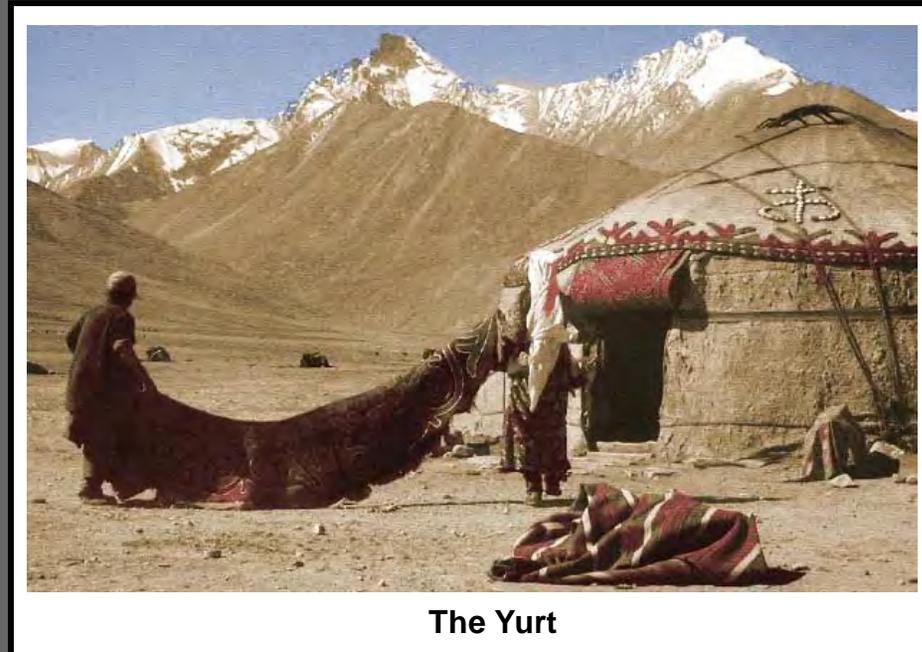
**BACKGROUND**

**THE NATURE OF SHELTERS**



Yurts are felt-covered frame tents that have been used by nomadic herders throughout much of Central Asia for nearly 2,000 years.

- Commonly referred to as a Mongolian Felt or “Ger”, the lightweight design can be warm in arctic cold, yet cool in summer:
  - The original version was a round lattice wall structure made of wood rods covered with animal skins which could be rapidly disassembled and carried by oxen-drawn carts.
  - The roof ring (the most complex part) was a hoop of wood containing slots or holes that roof poles could lock into.



**The Yurt**

**Historic Precedents**

**BACKGROUND**

**THE NATURE OF SHELTERS**

Typical yurts are designed as portable, prefabricated structures. The frames and outer coverings fold into lightweight bundles that can be easily transported, assembled, and disassembled in a short time without any tools.

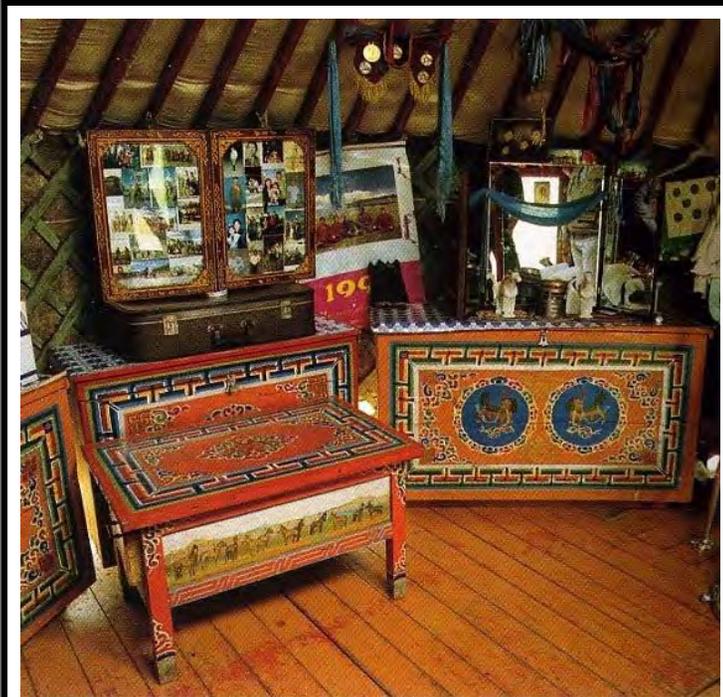


Historic Precedents

**BACKGROUND**

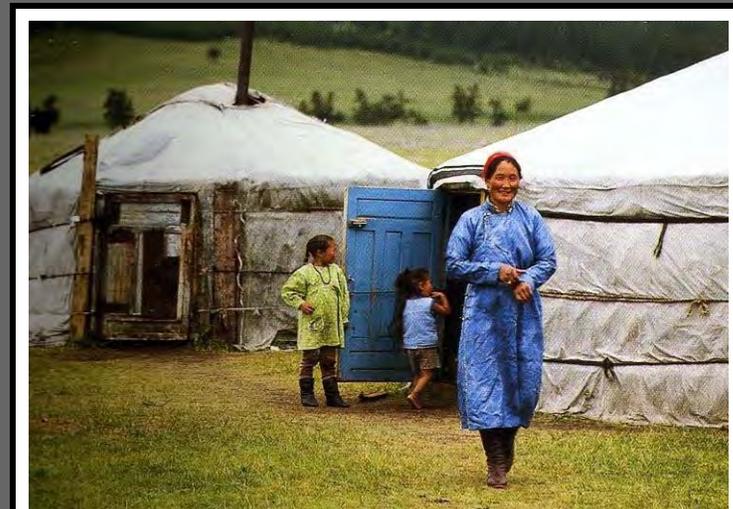
**THE NATURE OF SHELTERS**

**MOVE HOUSE**



**Shamanistic Alter in Mongolian Yurt**

The thick woolen waistcoats traditionally worn by nomadic herdsman are made of the same materials that cover their homes to maximize use of limited resources.



**The Yurt**

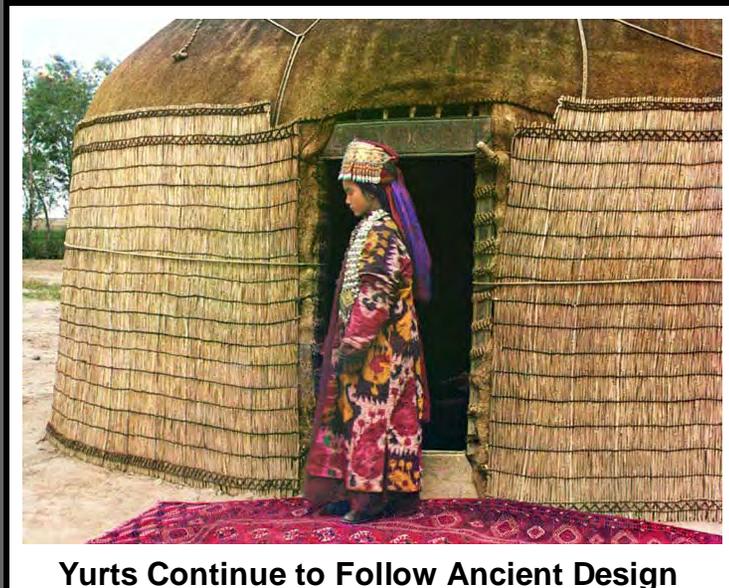
**Historic Precedents**

**BACKGROUND**

**THE NATURE OF SHELTERS**

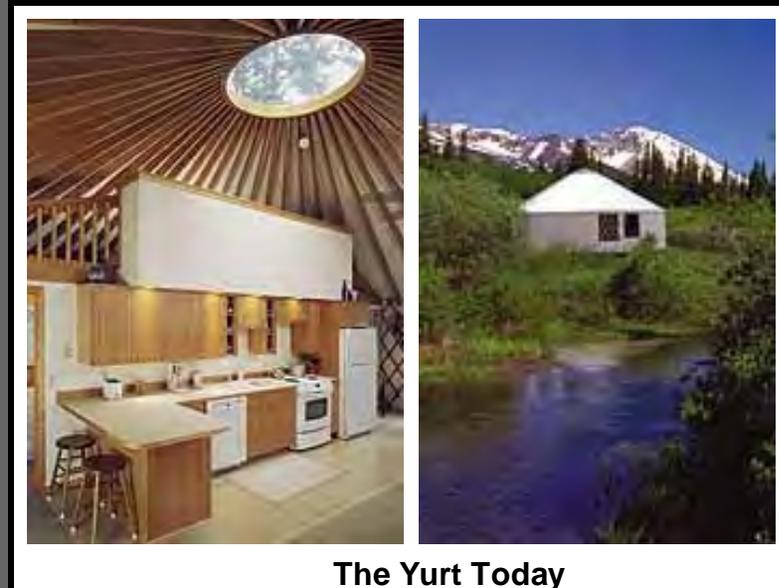


Yurts are still widely used in many of the most barren and inhospitable regions of the world, including the deserts of the Sahara and Gobi, the Central Asian Steppes, and in polar tundras.



**Yurts Continue to Follow Ancient Design**

Modern-day yurts, based on ancient design, provide low-cost structures for temporary housing, vacation homes/ cabins and other domestic applications.



**The Yurt Today**

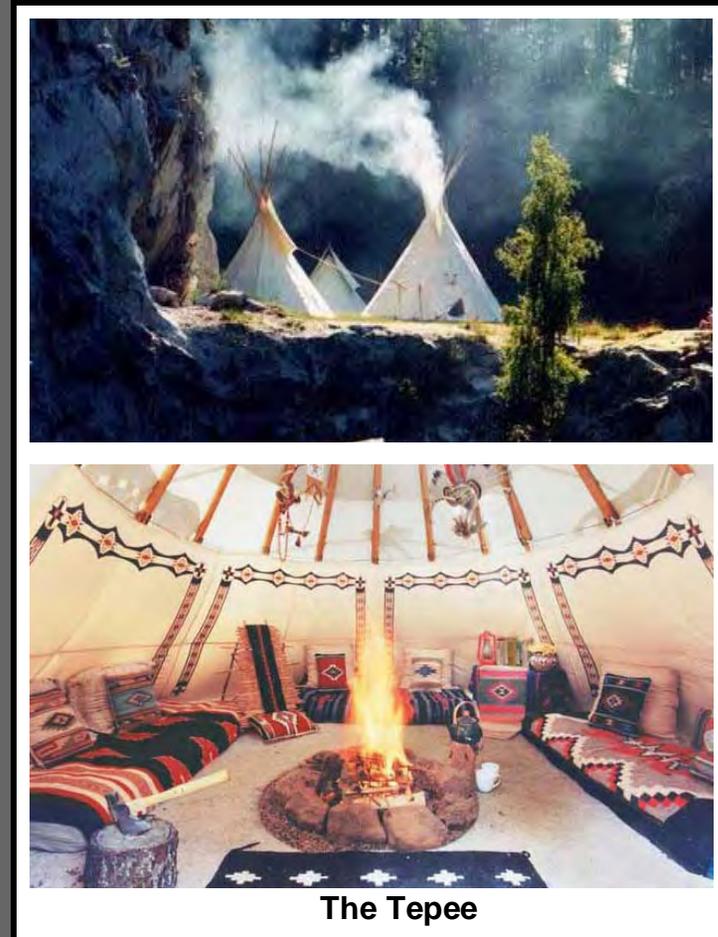
**Historic Precedents**

**BACKGROUND**

**THE NATURE OF SHELTERS**

The tepee tent structure used by Sioux and other Native American tribes provided survival protection in snow at below zero temperatures, and in coastal rain forests with hurricane force wind storms.

- The tents were designed to be easily set up and dismantled so that camps could be moved to follow bison and other game migrations:
  - The first construction step was to tie together three sapling poles to brace the structure.
  - Then a dozen or more long poles were lashed together and connected to the first three to form a tipped cone enclosure skeleton.
  - Animal skins covered the skeleton and a flap at the top opened and closed to release smoke from cooking via an updraft.

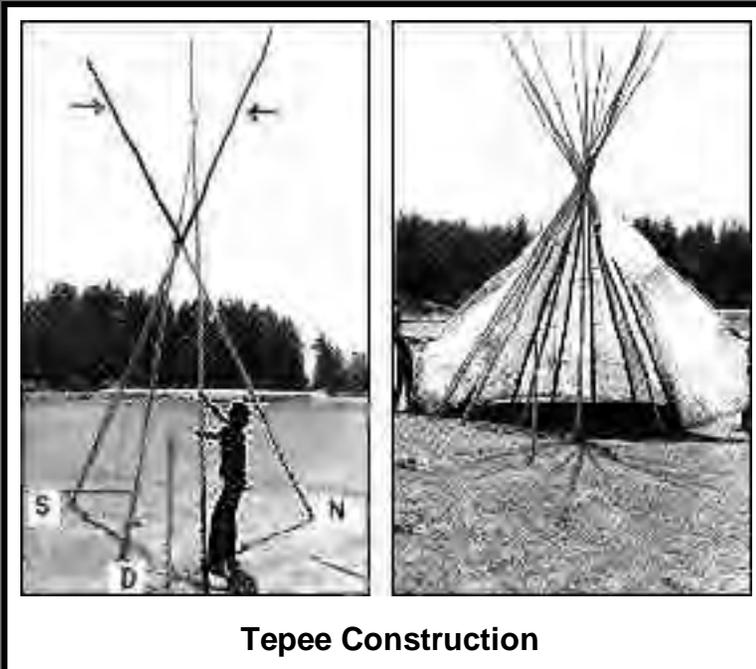


**The Tepee**

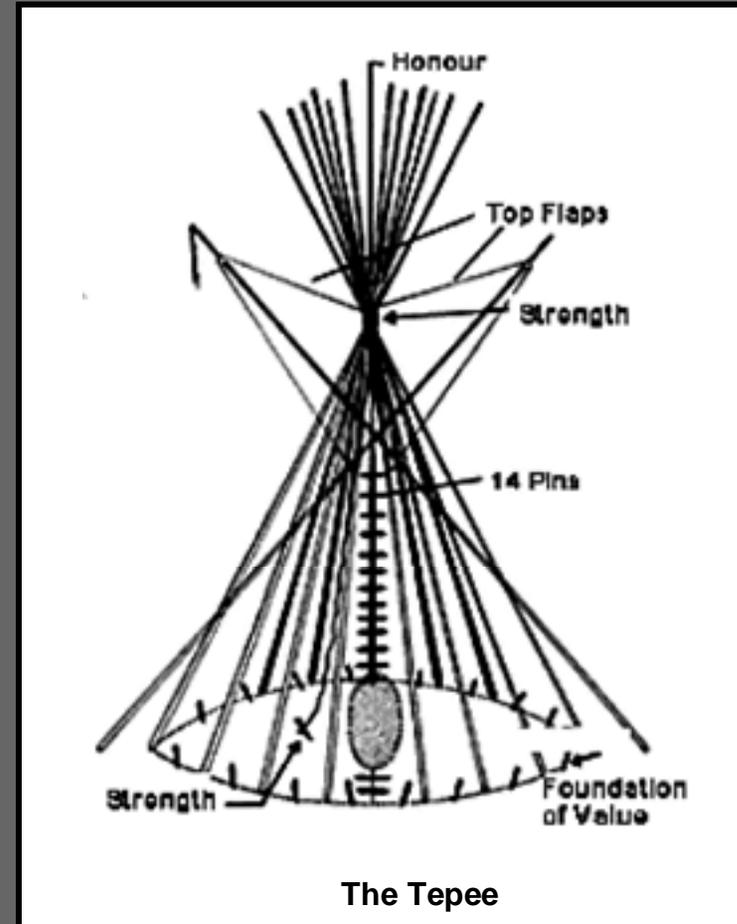
**Historic Precedents**

**BACKGROUND**

**THE NATURE OF SHELTERS**



Tepee Construction

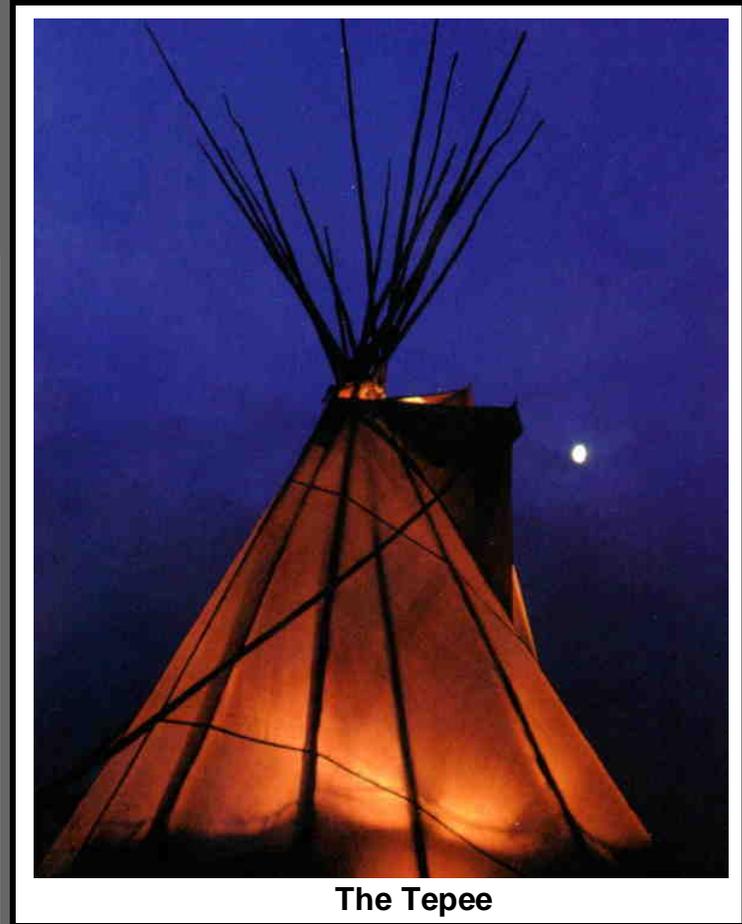


The Tepee

Historic Precedents

BACKGROUND

THE NATURE OF SHELTERS



Historic Precedents

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**BACKGROUND**

**THE NATURE OF SHELTERS**



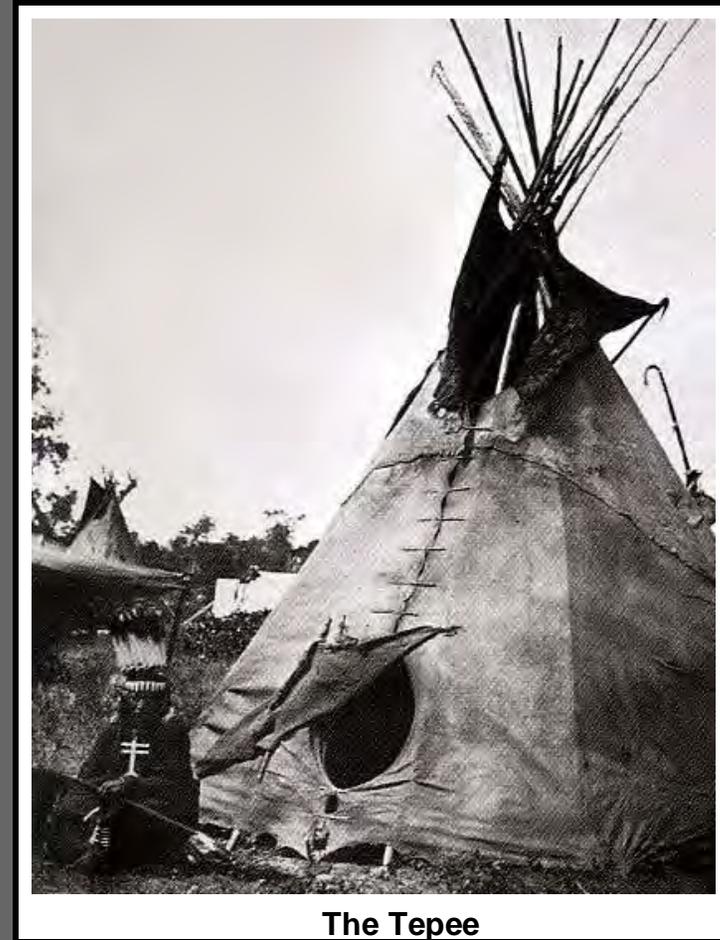
The ancestral American Indian tepee is the ancestor of many contemporary tent structures of ranging types, sizes and applications.

A-54  
MOVE HOUSE

### FEATHERWEIGHTS



Frei Otto's 1967 Expo Pavilion



The Tepee

Historic Precedents

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BACKGROUND

THE NATURE OF SHELTERS



Igloos are domes constructed of independent snow blocks that lean into each other and are shaped to fit without a supporting structure. In the traditional Inuit igloo, heat from a kullig (stone lamp) causes the interior to melt slightly. It then refreezes to create an ice sheet that adds strength.

- There are three general types of igloos of different sizes and uses:
  - The smallest are constructed as temporary shelter (“iglooits”) while out on land or sea ice for one or two nights.
  - Intermediate-sized semi-permanent igloos are single room dwellings used by one or two families, and are sometimes grouped together to form villages.
  - The largest are temporary buildings which may have several rooms and house up to 20 people for special events such as community feasts and dances.



**The Igloo**

**Historic Precedents**

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**BACKGROUND**

**THE NATURE OF SHELTERS**



1. Blocks are cut from dry, hard snow.



2. Blocks are placed in circle that spirals up.



3. Walls are built up to slant inward.



4. Entrance is cut.

**Igloo Construction Steps**



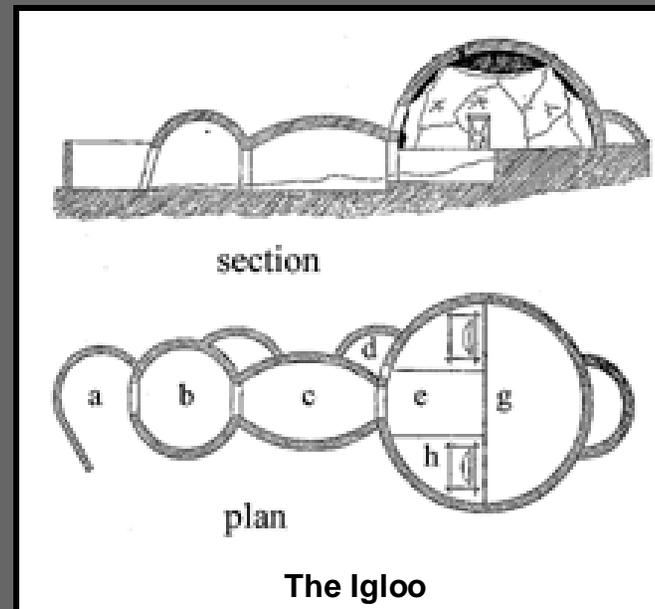
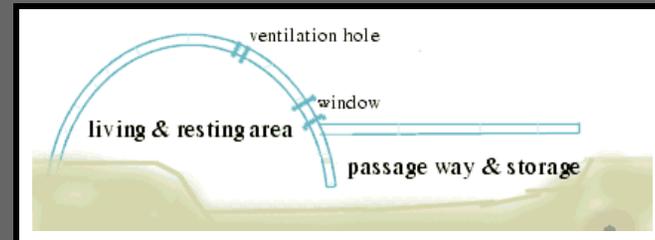
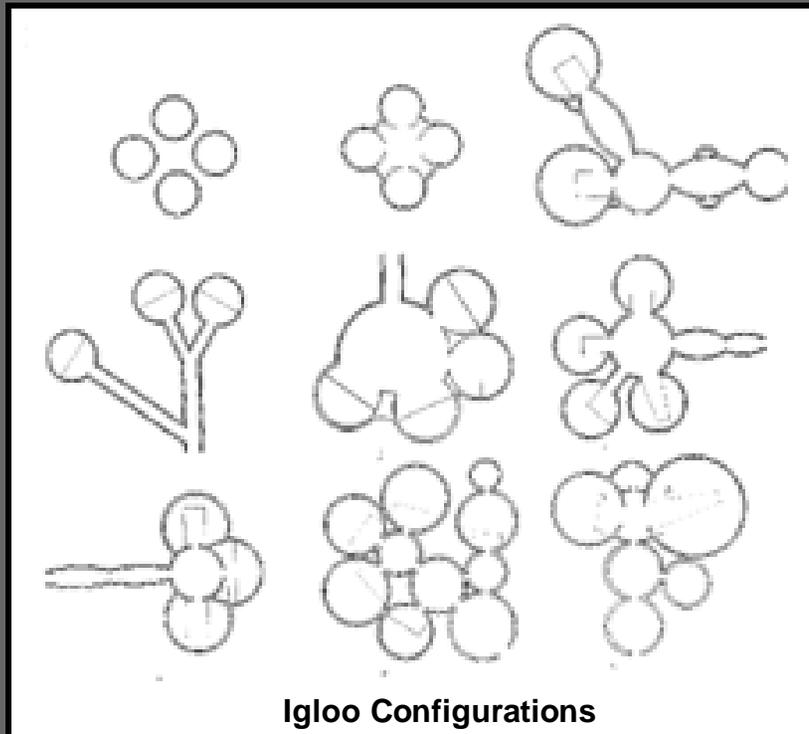
**The Igloo**

**Historic Precedents**

**BACKGROUND**

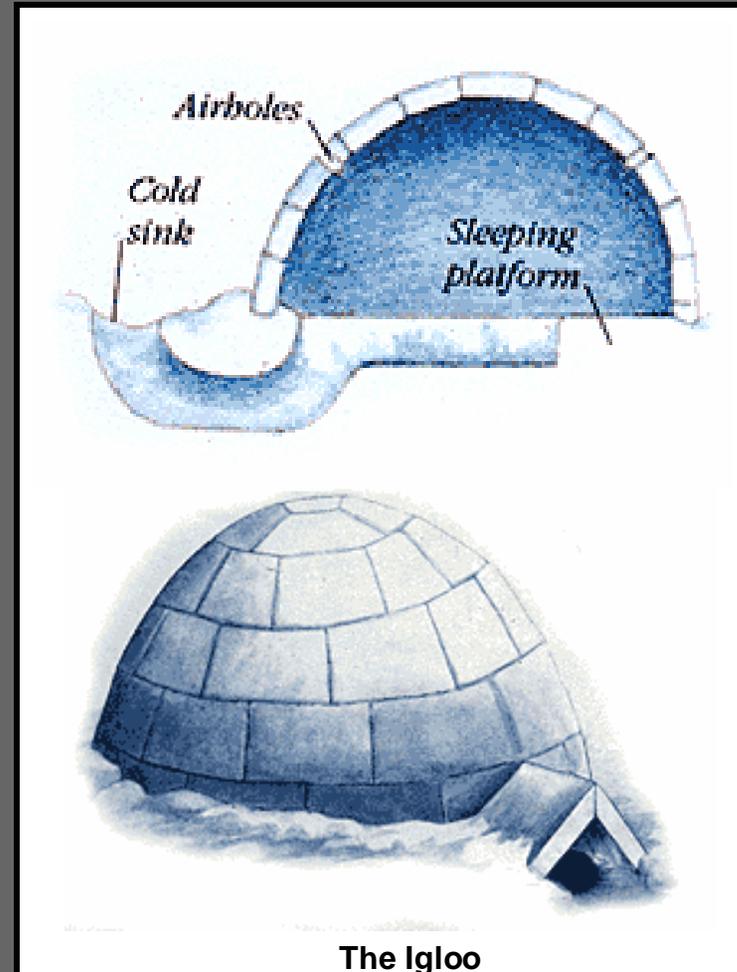
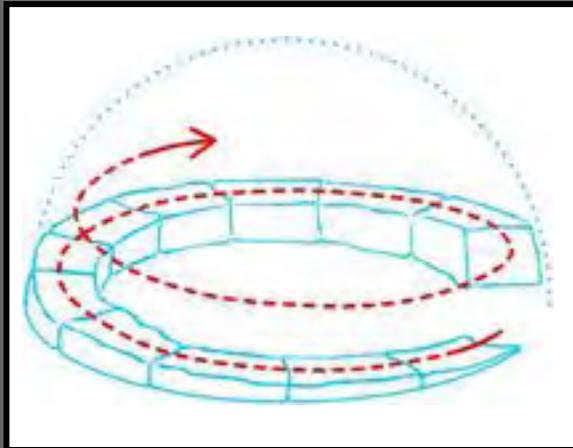
**THE NATURE OF SHELTERS**

Large igloos can be created by connecting others of various sizes.



Historic Precedents

Hot air from the body rises and is trapped inside the dome. Cold air falls into a sink and flows away to the outside.



**The Igloo**

Historic Precedents

**BACKGROUND**

**THE NATURE OF SHELTERS**

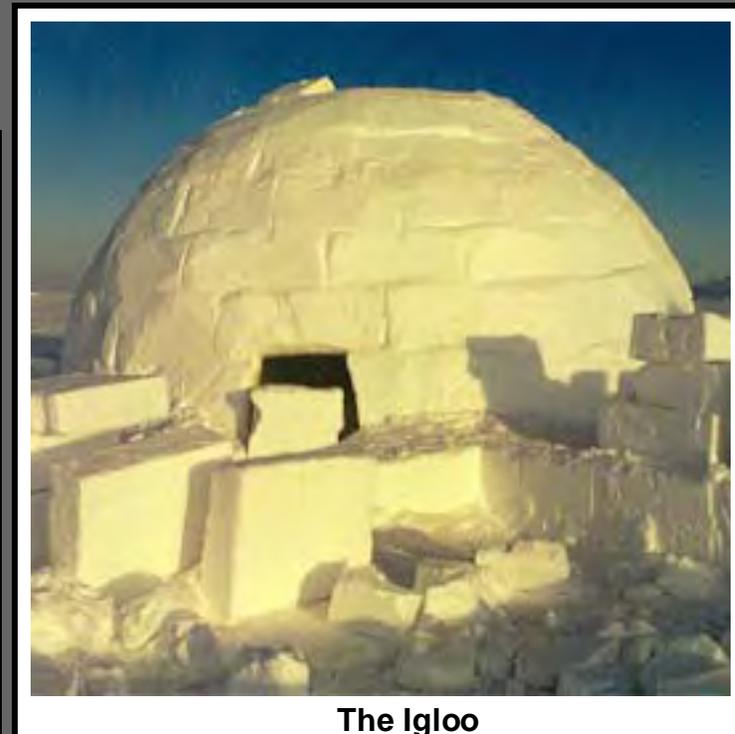
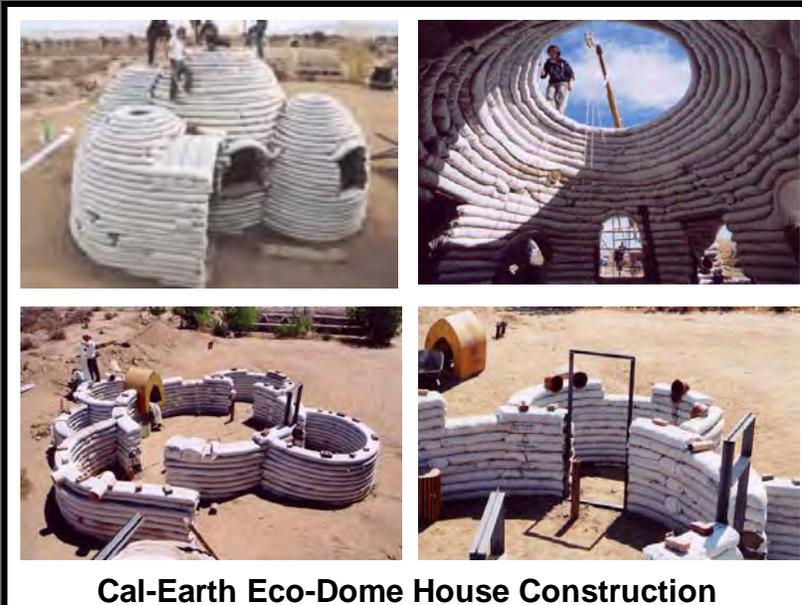


Earth-filled Eco-Domes created by the Cal-Earth Institute apply a construction concept similar to igloos.

WIKIPEDIA

Nader Khalili

Cal-Earth



Historic Precedents

BACKGROUND

THE NATURE OF SHELTERS

American prairie sod houses were common from the earliest days of settlement to the beginning of the 20<sup>th</sup> Century.

- The small houses were built using stacked layers of raw earth (not rammed-earth, puddled earth or earthen brick techniques used by Eastern Europeans):
  - Individual bricks were cut with special plows, or by hand with an axe or shovel.
  - Plant root systems contained in the sod held the bricks together.
  - Roofs were made from rough or planed timber, and were often covered with more sod.

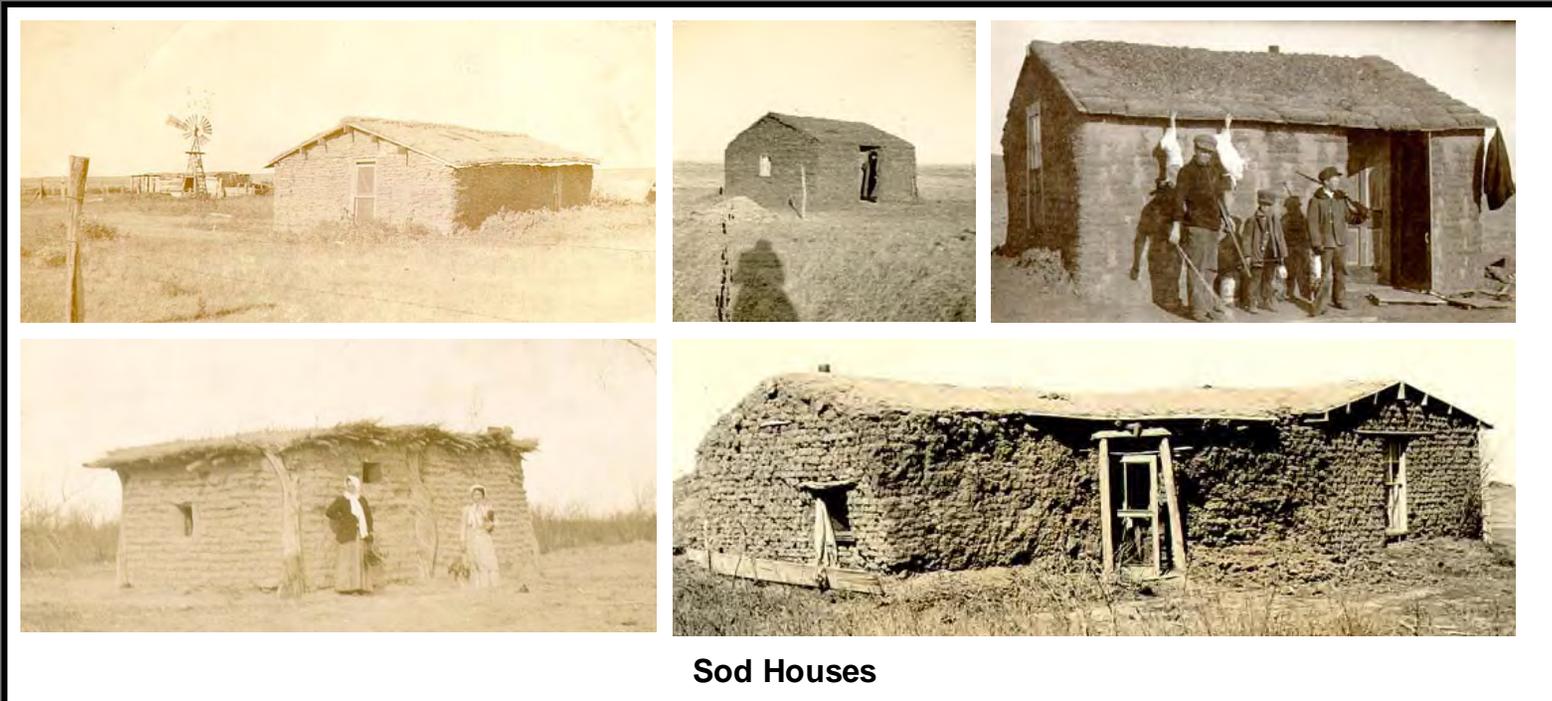


**Sod Houses**

**Historic Precedents**

**BACKGROUND**

**THE NATURE OF SHELTERS**



Historic Precedents

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**BACKGROUND**

**THE NATURE OF SHELTERS**

More permanent earth brick structures were made of adobe, which mixed mud and straw together into bricks that were dried for greater strength.

- Gaps between the bricks were filled with more mud to block out wind, rain and insects.
  - Since adobe could not stand up well during long periods of rain, the structures were mostly built in very dry locales.
  - Rammed-earth and clay bricks gained broad applications for modern habitats.



**Adobe House**



**Sod House**

**Historic Precedents**

**BACKGROUND**

**THE NATURE OF SHELTERS**



Log cabins could be considered to mark the beginning of American architecture, although their broad use greatly declined after saw mills came into existence in the early 20<sup>th</sup> Century.

- The original type was built with logs of different types set vertically into trenches to create walls, followed by the more familiar type with logs laid horizontally with interlocking notched ends:
  - Scandinavian construction techniques allowed for faster and tighter construction by hollowing out log undersides to fit smoothly over lower ones.
  - Many cabins had a sleeping loft in the roof peak, and some had a substantial second storey.
  - Most early versions had dirt floors, but plank flooring was often added later along with room additions as families grew and prospered.

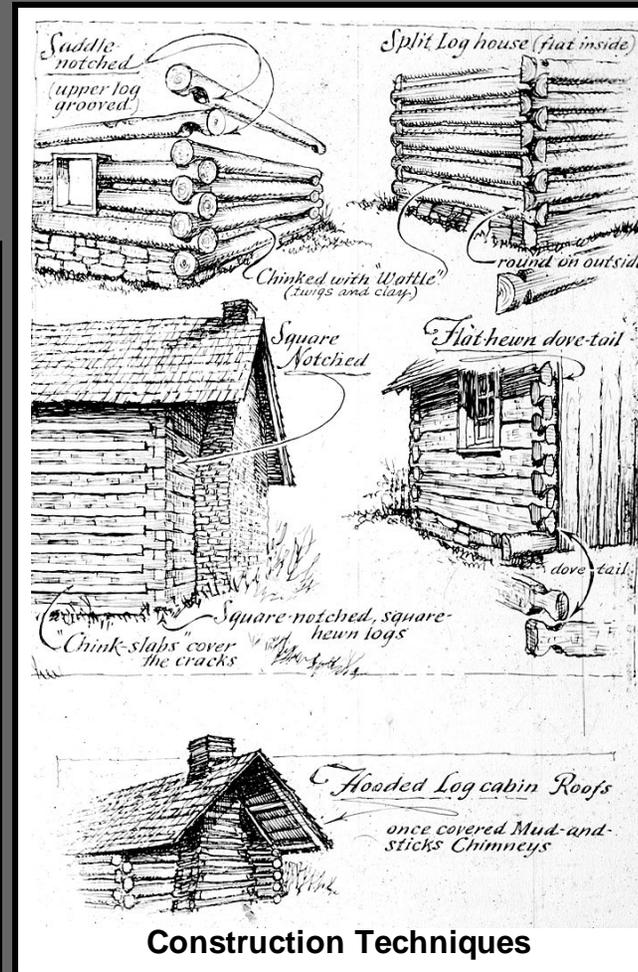
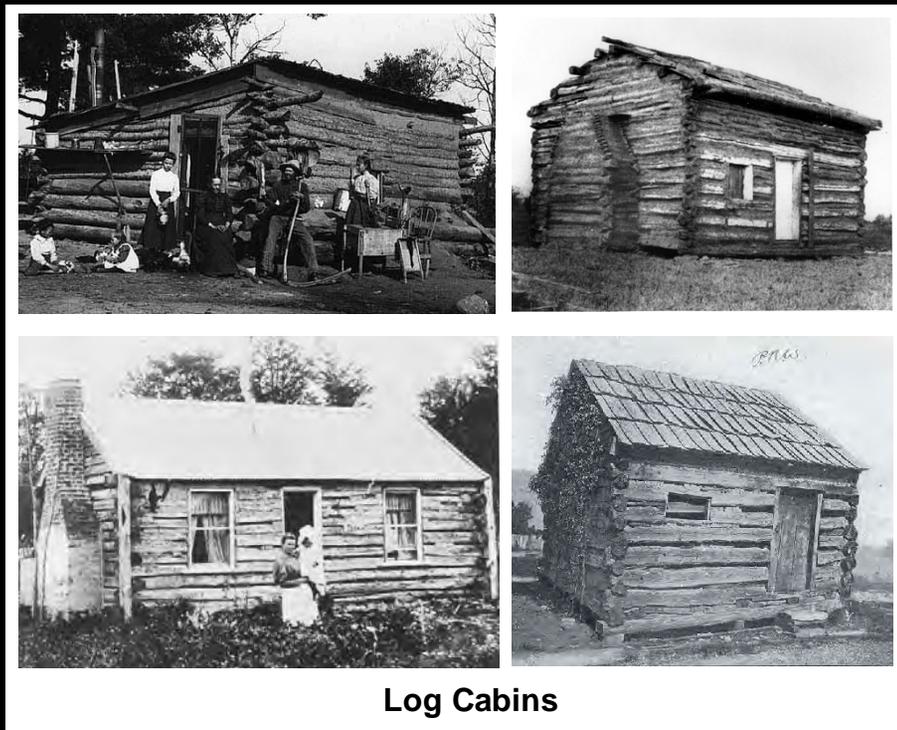


**Log Cabins**

**Historic Precedents**

**BACKGROUND**

**THE NATURE OF SHELTERS**



Historic Precedents

BACKGROUND

THE NATURE OF SHELTERS

Early homes were typically set to true compass points to help occupants keep their directions straight, particularly on the prairie where the lack of landmarks and presence of cloudy skies could lend confusion. Doors were placed on the south to let in light and mark passage of time as shadows moved along the floor.



**Log Cabins**

**Historic Precedents**

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**BACKGROUND**

**THE NATURE OF SHELTERS**



Windows and doors were cut after walls were up, and short blocks of logs were inserted for ends to rest on. Open wall spaces were chinked with long wedges split from logs, and mixtures made from clay and sand or grass were plastered over them for tighter seals.



Exterior Corner



Typical Interiors

Historic Precedents

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## BACKGROUND

## THE NATURE OF SHELTERS



Shigeru Ban

FEATHERWEIGHTS

Shigeru Ban's Paperlog Houses were first used for victims of the Kobe earthquake in 1995.

- The habitats are designed to provide emergency accommodations that can be set up on short notice and with little effort or expense:
  - Fifty prototypes were constructed of simple cardboard tubes using plastic fasteners which were easy to connect.
  - Tarpaulin roofs covered the units.
  - Foundations were made of worn-out beer crates filled with sand for stability.
  - Tests proved that the construction resisted termites.



**Paperlog Houses (Log Cabins)**

Historic Precedents

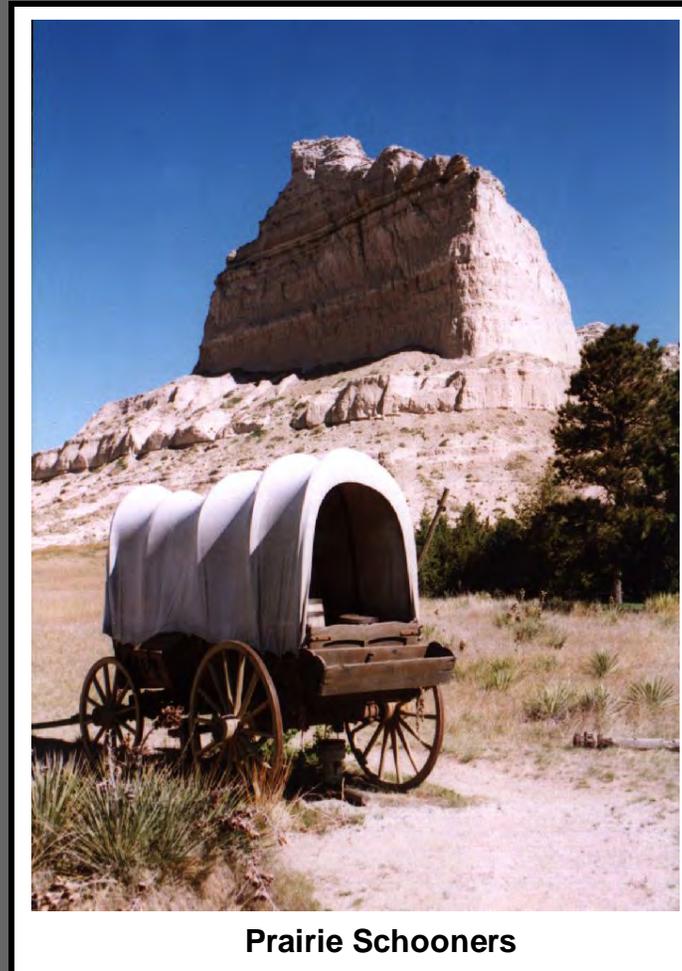
**BACKGROUND**

**THE NATURE OF SHELTERS**



The "Prairie Schooner" was a half-sized variant of the covered Conestoga wagon used as a freight carrier. It functioned as a "mobile home" for American pioneers during long, hard westward journeys along the Oregon Trail, Highland Trail, Santa Fe Trail and Chisholm Trail.

- The first Conestoga Wagons were introduced by Mennonite German settlers in Pennsylvania around 1725, and a later, smaller version was covered with a white canvas roof:
  - Broad wheels were added for travel on dirt paths, in mud, on grass and in mild mountain terrains.
  - Many were manufactured by the Studebaker brothers, predecessors of Studebaker automobiles, which followed through the late 1960's.



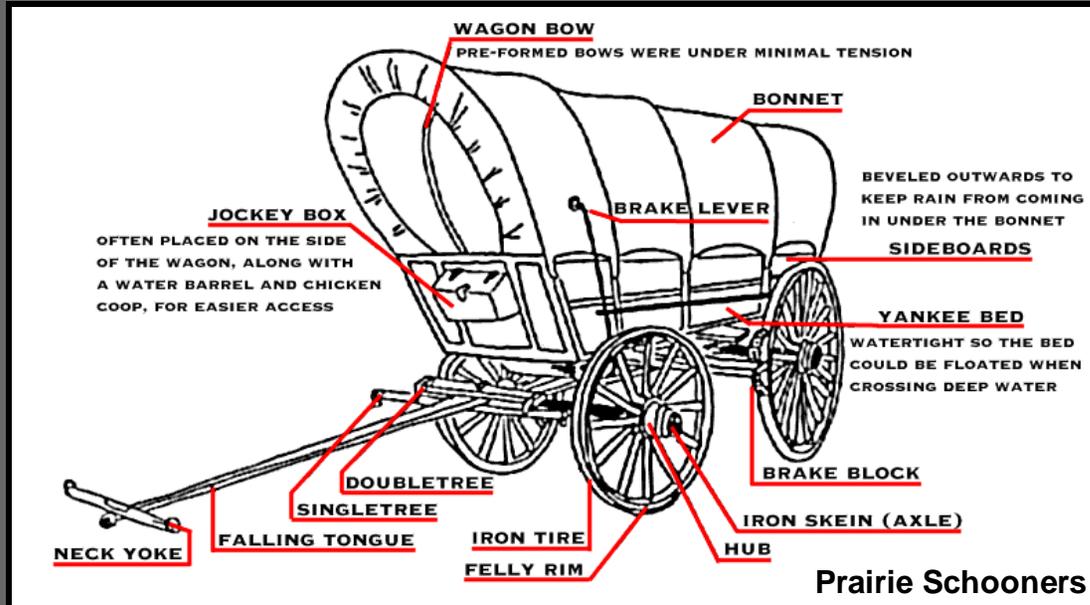
**Prairie Schooners**

**Historic Precedents**

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**BACKGROUND**

**THE NATURE OF SHELTERS**



Historic Precedents

BACKGROUND

THE NATURE OF SHELTERS

Prairie Schooners carried items essential for survival on the rough journeys. Typically included were water barrels, a butter churn, a shovel, an axe, a tar bucket, a chicken coop, a feed trough for livestock, and tools for making frequent wheel repairs.



**Prairie Schooners**



**Life on the Trails**

**Historic Precedents**

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**BACKGROUND**

**THE NATURE OF SHELTERS**



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**BACKGROUND**

**THE NATURE OF SHELTERS**



Prairie Schooners that expanded settlement of the American West were precedents for travel trailers that supported nation-wide tourism as well as habitat modules that are opening new space frontiers.



**Prairie Schooners**



**Airstream Trailer**



**Space Station Modules**

**Historic Precedents**

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**BACKGROUND**

**THE NATURE OF SHELTERS**



Shelters have been developed in response to special interests and needs of particular user sponsors and occupant groups.

- Design requirements and features have been determined by entities, which include:
  - International military agencies.
  - Emergency disaster response organizations.
  - Science and exploration planners.
  - Commerce and industry building markets.



**Types of Shelter Sponsors**

**Priorities and Requirements**

**BACKGROUND**

**THE NATURE OF SHELTERS**

Many different shelter applications share common design priorities.

- Representative requirements include:
  - Efficient and versatile transportability to destination sites.
  - Ability to protect users from extreme weather and climate conditions.
  - Easy and rapid construction/ deployment by unskilled labor without special tools and training.
  - Adaptation to variable and rugged terrain features with little or no site preparation.



### Priorities and Requirements

## BACKGROUND

## THE NATURE OF SHELTERS

Different types of shelters share common support requirements.

- Integrated and augmented systems typically include:
  - Utilities (water, waste treatment, HVAC and power) equipment and/ or connections.
  - Thermal insulation materials and devices.
  - Fire and smoke protection safeguards.
  - Security from external threats/ intrusions.



**Common Requirements**

**Priorities and Requirements**

**BACKGROUND**

**THE NATURE OF SHELTERS**



**PREFAB**

A variety of contemporary shelters take advantage of prefabricated construction processes.

- Prefabricated units and components offer some important advantages over conventional construction methods:
  - They are not dependent upon availability of local materials.
  - They minimize dependence upon local construction skills and tools.
  - They enable rapid, low-labor implementation for readiness.
  - They optimize efficient production methods and quality controls.



**Prefabricated Systems**

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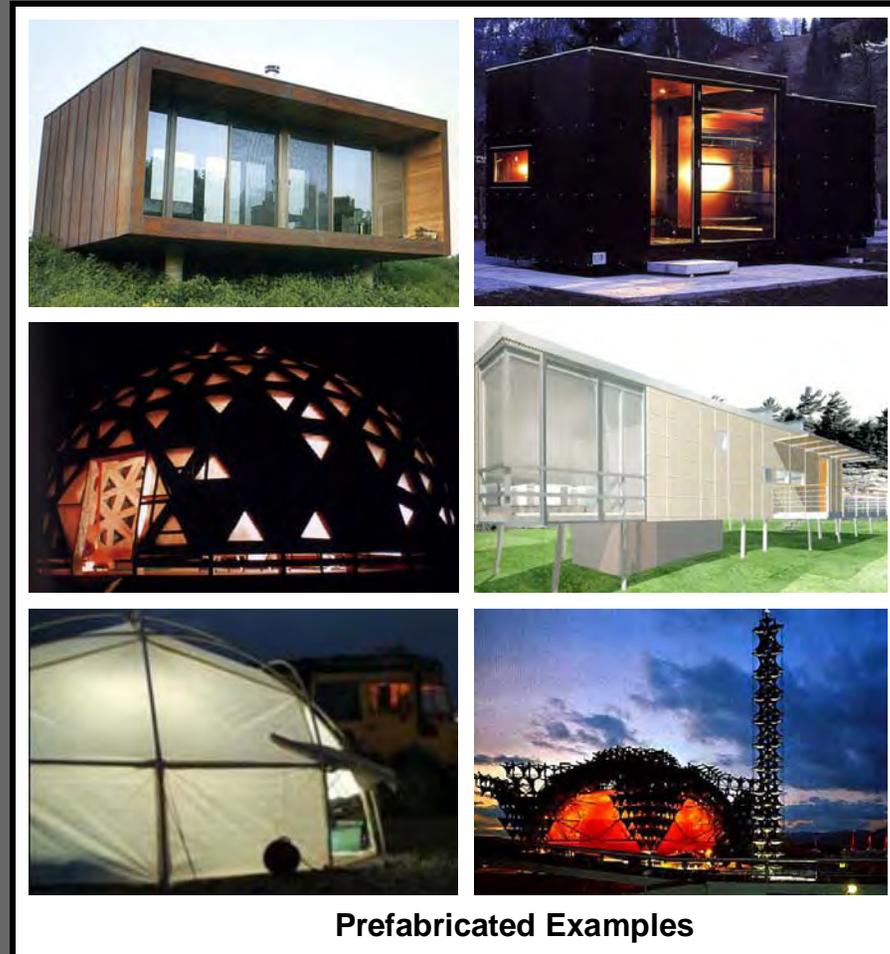
**BACKGROUND**

**THE NATURE OF SHELTERS**



Some shelter types are prefabricated as entire units, while others are assembled at the destination sites from prefabricated mass-produced components.

- Key types represented later in this presentation include:
  - Fixed-volume and expandable modules.
  - Constructed shell and panel structures.
  - Soft tensile structures.
  - Special structures (modular complexes, suspended constructions and space frames).



**Prefabricated Examples**

**Prefabricated Systems**

**BACKGROUND**

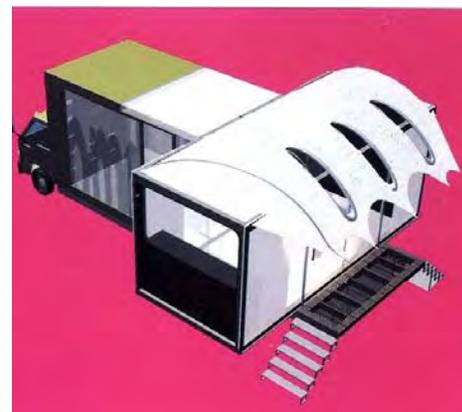
**THE NATURE OF SHELTERS**



Prefabricated systems range from small temporary single-space modules to large permanent dwellings and complexes.

- Different types offer various advantages, limitations and applications:
  - Modular approaches typically enable utilities and other support systems to be integrated prior to delivery to the destination sites to facilitate fast/ easy implementation, but tend to be volume-limited with sparse amenities.
  - Component approaches enable more expansive, complex and luxurious habitats to be created, but often impose substantial labor, time and tools for construction.

## PREFAB MODERN



**Module Approach**

## PREFAB



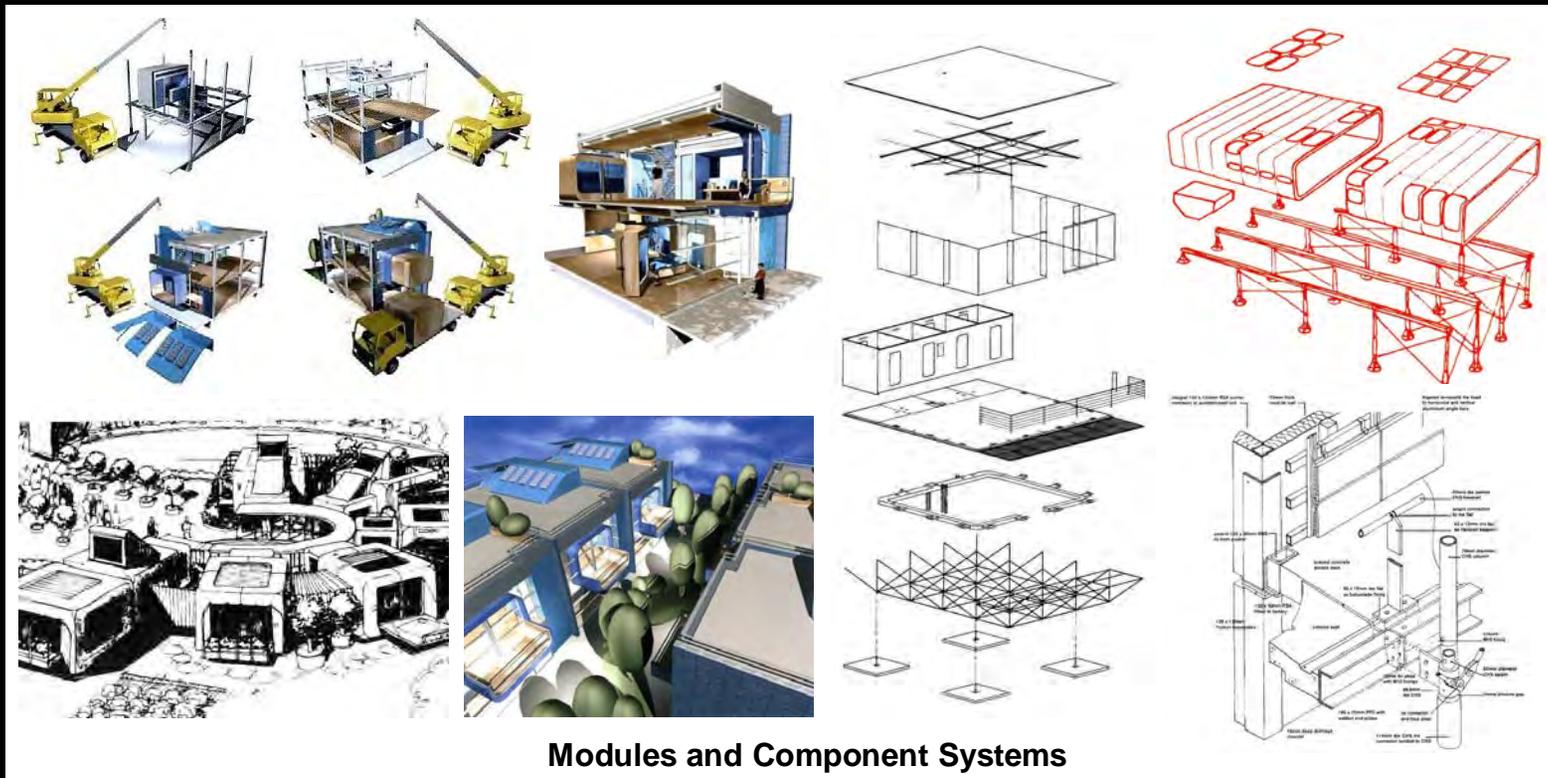
**Component Approach**

**Prefabricated Systems**

**BACKGROUND**

**THE NATURE OF SHELTERS**

**PREFAB**



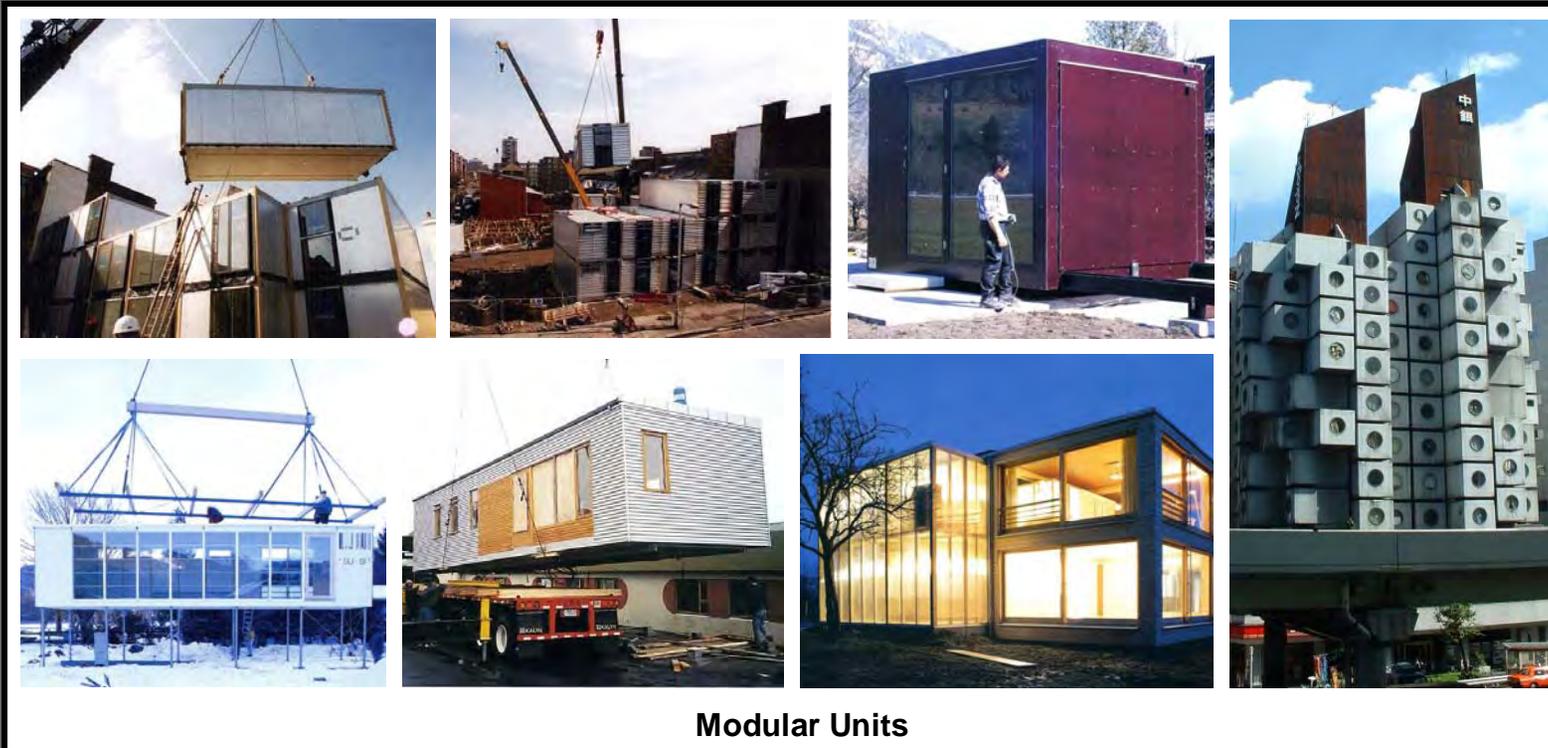
**Modules and Component Systems**

**Prefabricated Systems**

**BACKGROUND**

**THE NATURE OF SHELTERS**

**PREFAB**



**Prefabricated Systems**

**BACKGROUND**

**THE NATURE OF SHELTERS**

# SECTION B : EARTHSCRAPERS

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Ancient and current cultures have survived by learning to use their bare hands and the earth beneath their feet to create shelters for protection from weather and predators, that would otherwise threaten their safety.

- Some of these approaches have involved using natural geological features for shielding from wind, rain, and snow.
- Some have used indigenous natural and man-made materials at the sites to create temporary/makeshift shelters
- Some have formed structures from common and abundant surface materials, formed as bricks or complete walls
- And some have been constructed using plant material that are lashed together, or stacked in cut bales



**Shelter Approaches**

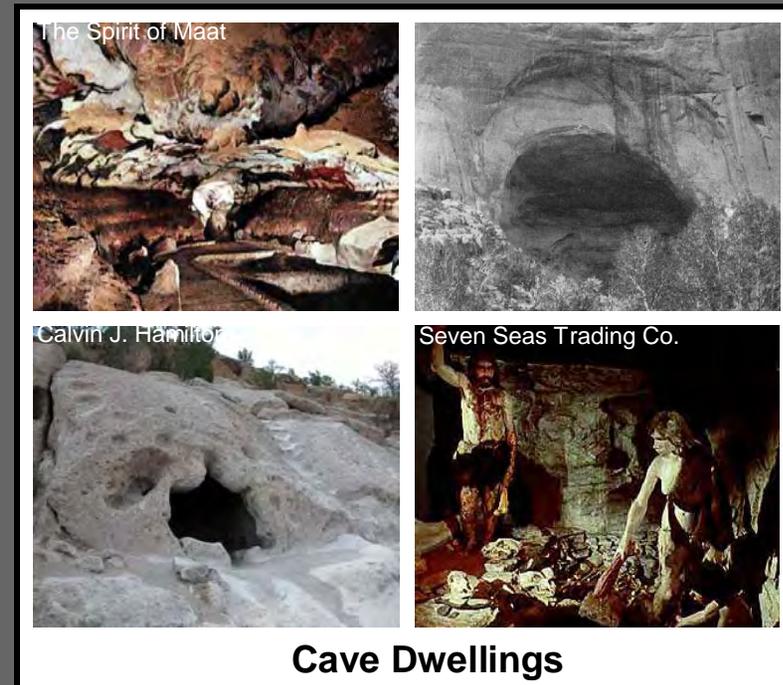
**EARTHSCRAPERS**

**IN-SITU CONSTRUCTION**



The Paleolithic or Early Stone Age period (popularly known as the “Ice Age”) was characterized by climate fluctuations between very cold (glacial) and warm (interglacial) conditions. During this time, our early ancestors evolved from African origins, migrated across Europe and Asia, and developed into modern humans.

- Many populations of these early people owed their survival to the existence of natural caves:
  - Evidence of early cave life dates back about 230,000 years through the discovered remains of Neanderthal skeleton fragments and tools in Wales.
  - Caves and other natural cavities have continued to provide shelters through modern times, and may find new applications as humans takes up residence on the Moon and other planets.



Natural Formations

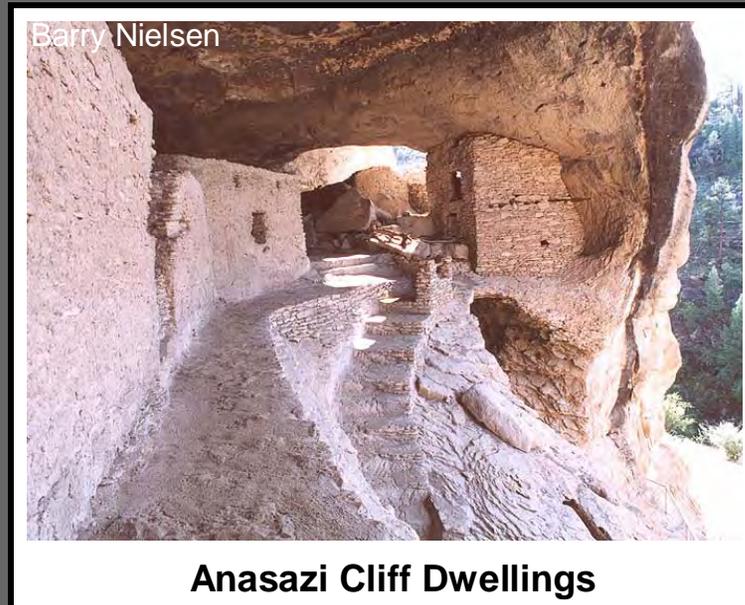
**EARTHSCRAPERS**

**GOING UNDERGROUND**



Stone dwellings built into caves or large shelves in sheer rock canyon walls have provided principal forms of shelter in regions where these features exist.

- Extensive cliff dwelling communities were established by Anasazi populations in Colorado between 1200 BC and AD 1300:
  - Most were built on south-facing ledges in deep sandstone canyons to provide solar heat in the winter, and cool shade from overhanging cliff lips in the summer.
  - Agricultural fields were maintained on mesas above, and sometimes in broader canyons below.
  - Access was achieved by a series of small hand- and toe-holds in the steep sandstone walls.



**Anasazi Cliff Dwellings**

Natural Formations

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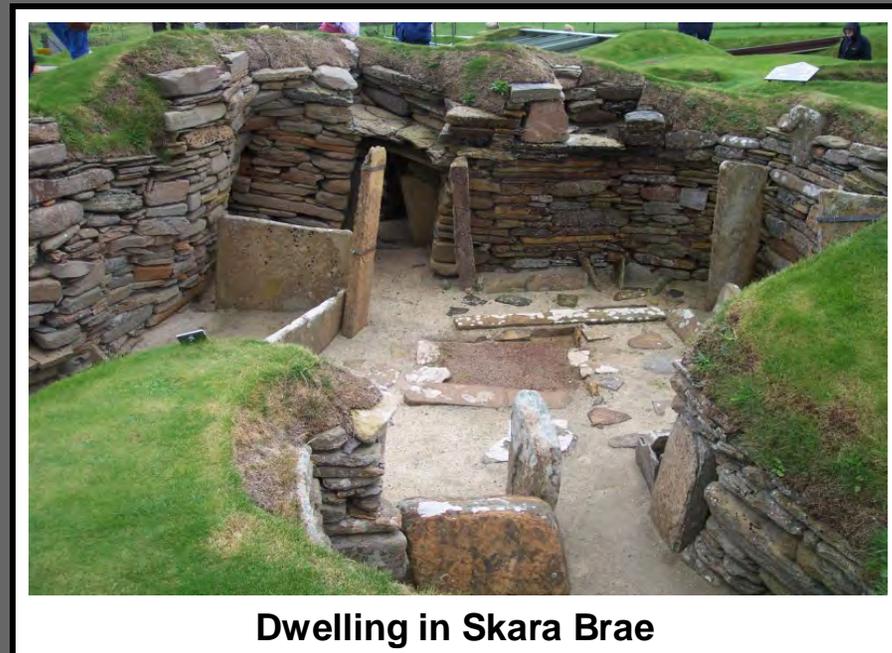
**EARTHSCRAPERS**

**GOING UNDERGROUND**



Some populations have excavated shelters into earth and rock mounds where natural caves didn't exist.

- Neolithic inhabitants near the Bay of Skail off northern Scotland occupied such habitats from 3100 BC to 2500 BC (until climate change created much colder and rainier conditions):
  - The dwellings were built into mounds (or "middens") which provided insulation against cold, and a small degree of stability.
  - They typically provided about 40m<sup>2</sup> of space, with a large square room containing a hearth for heating and cooking.
  - Drift wood and whalebone covered with turf hatch served as roofs.



**Dwelling in Skara Brae**

Excavated Dwellings

**EARTHSCRAPERS**

**GOING UNDERGROUND**

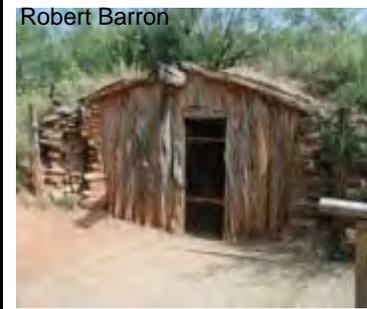
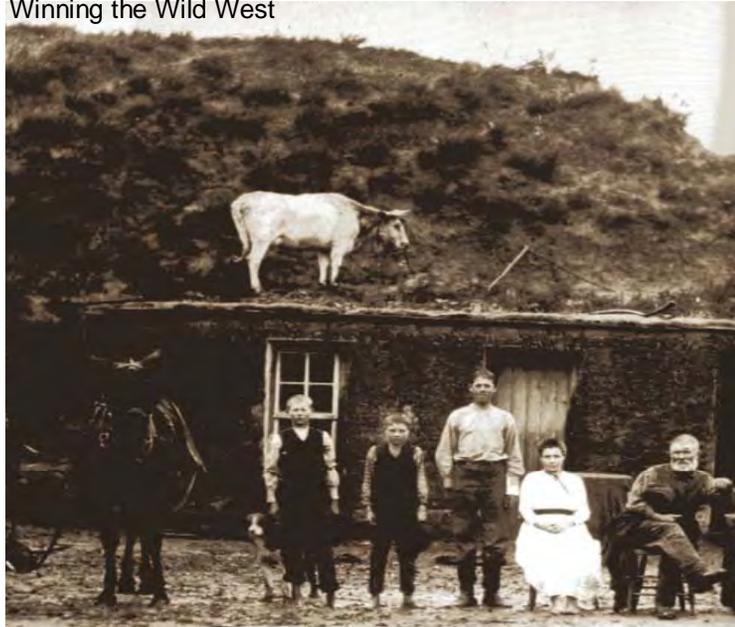


Due to the scarcity of trees for construction, many early settlers of the US Great Plains dug living shelters into hills and sloping sections of trails and riverbeds.

B-6

Doors were made out of any available materials, including skins and wagon covers. Some had fronts constructed of stacked logs, and sod coverings on entrance roofs.

Winning the Wild West



Robert Barron

Collections Canada

**Pioneer Dugouts**

Excavated Dwellings

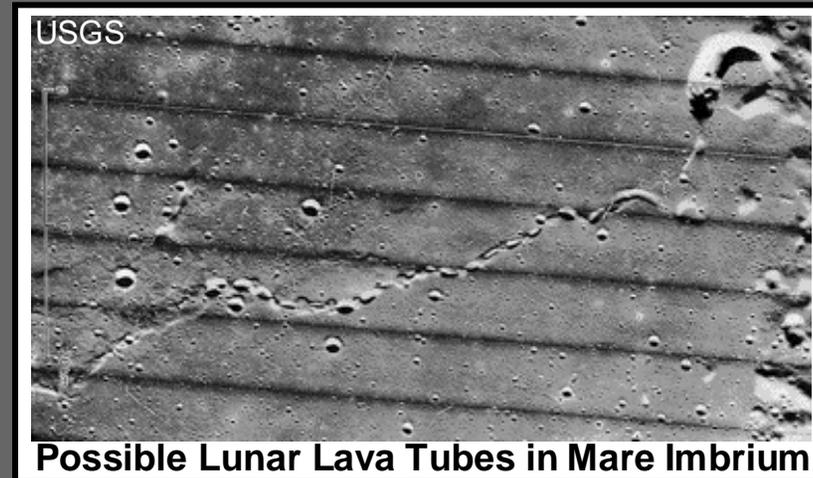
**EARTHSCRAPERS**

**GOING UNDERGROUND**



Learning to make resourceful use of available in-situ materials may prove to be essential to create future shelters on the Moon and Mars.

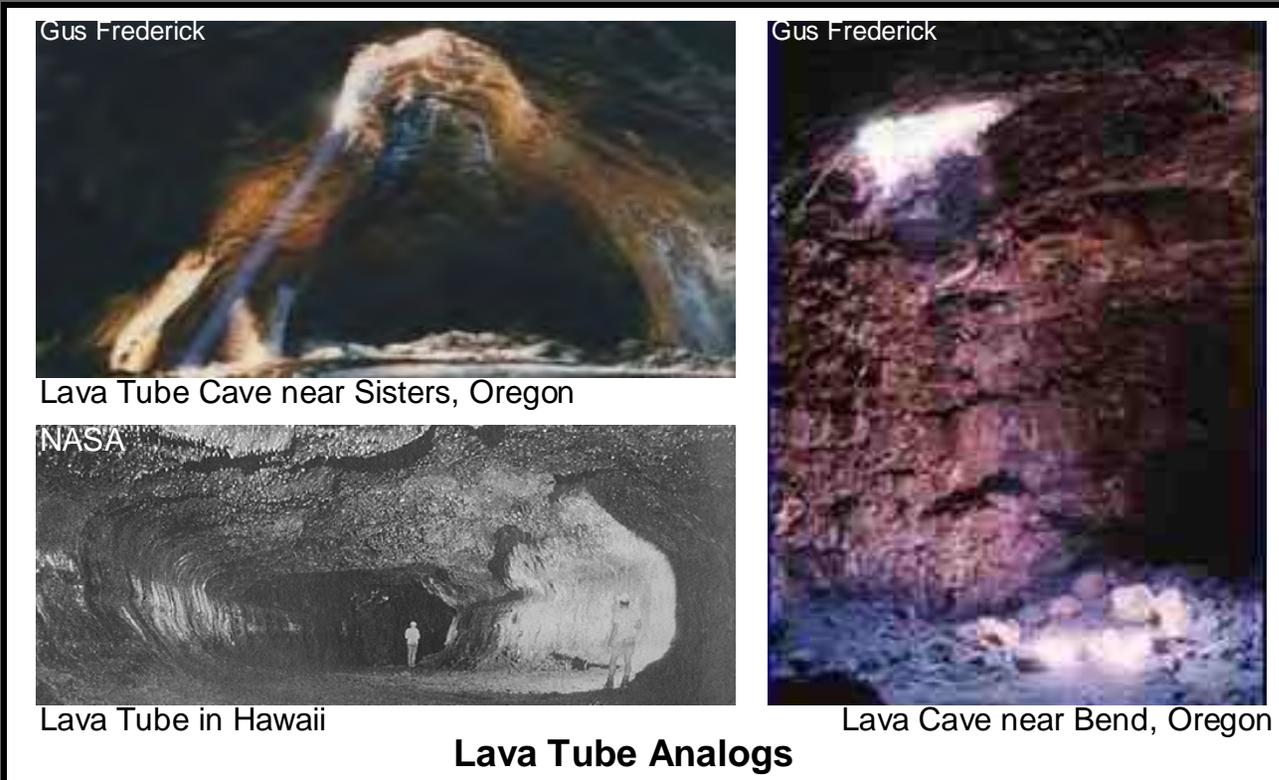
- Since the Moon has no atmosphere to provide shielding from harmful solar and cosmic radiation, and Mars has very little atmosphere, many proposals have been advanced to place habitats underground.
  - Some advocate locating pressurized modules in existing lava tubes which are believed to exist under the surface in certain areas.
  - This concept, if pursued, would apply the same general approach used by early cave dwellers to take advantage of natural conditions.



Space Applications

**EARTHSCRAPERS**

**GOING UNDERGROUND**



Space Applications

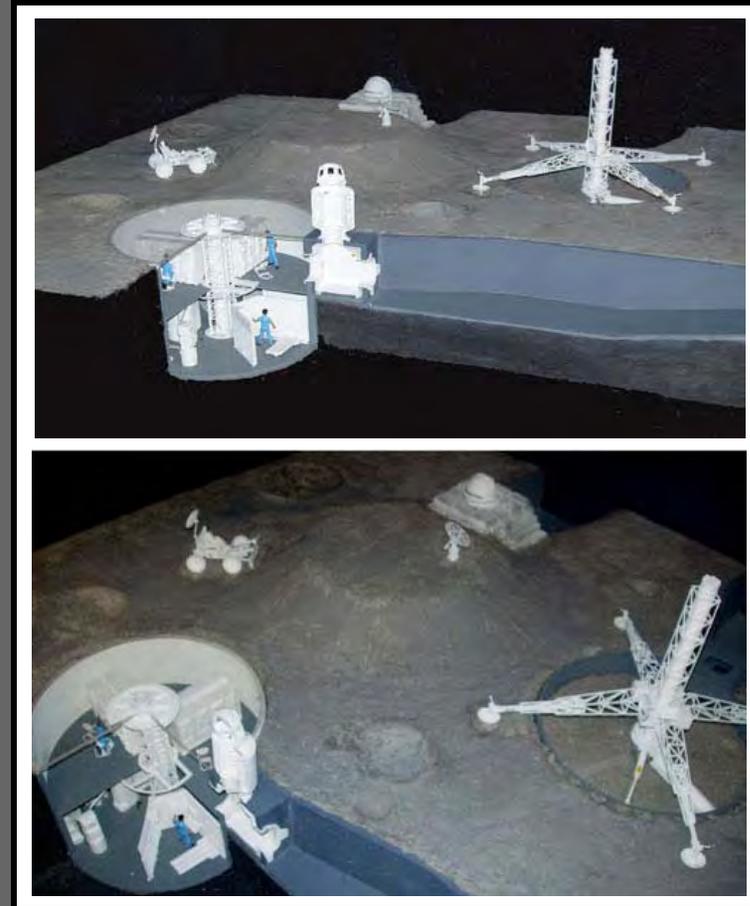
**EARTHSCRAPERS**

**GOING UNDERGROUND**



SICSA has proposed an in-situ construction approach which would excavate a pressurized habitat core into a lunar or Mars surface. This would avoid the need to transport and land modules.

- An automated auger system would be delivered to undertake the coring process:
  - A microwave element at the end of the auger would sinter the “soil” (regolith) to create a gas pressure liner.
  - Interior partitioning, floors, and roof systems would be made from cast basalt comprising much of the regolith.
  - Prefabricated pressure hatches and airlocks would be delivered and integrated.
  - Excavated regolith from the coring would be placed on top for radiation shielding.



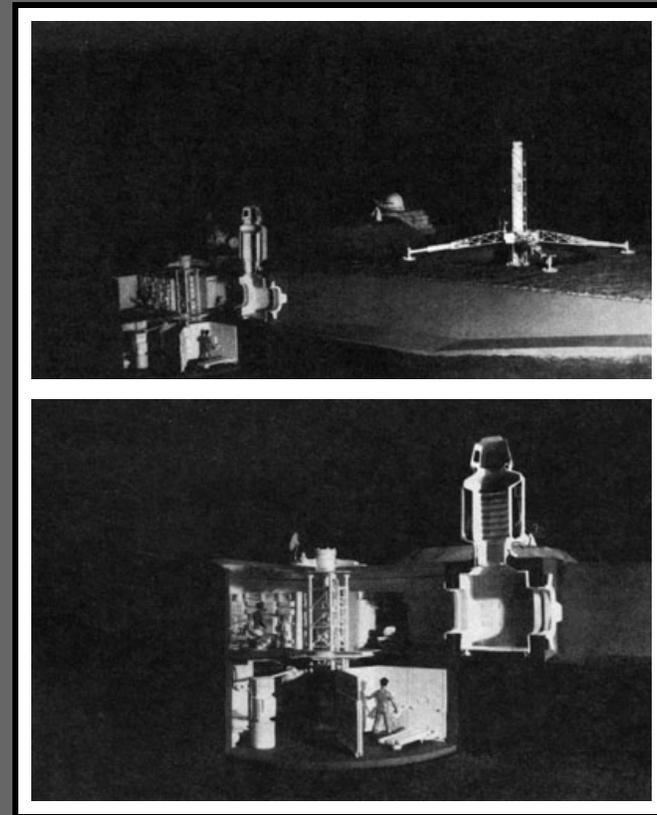
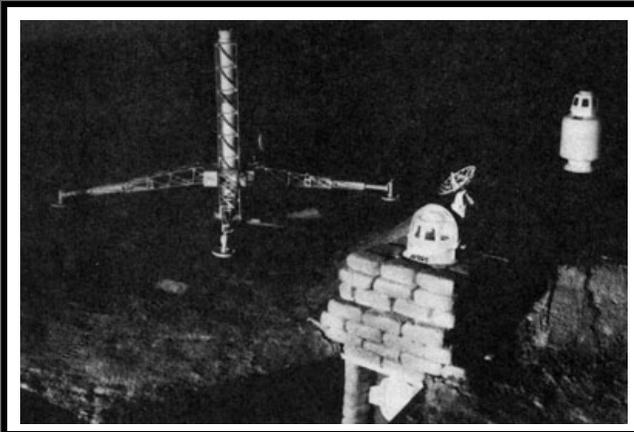
Space Applications

**EARTHSCRAPERS**

**GOING UNDERGROUND**

Proposed facility components:

- Sintered/ cast roadways and landing pads.
- Excavated/ sintered pressurized habitat with cast slab airlocks.
- Cast block and slab exterior/ interior structures (floors/ walls/ roof).

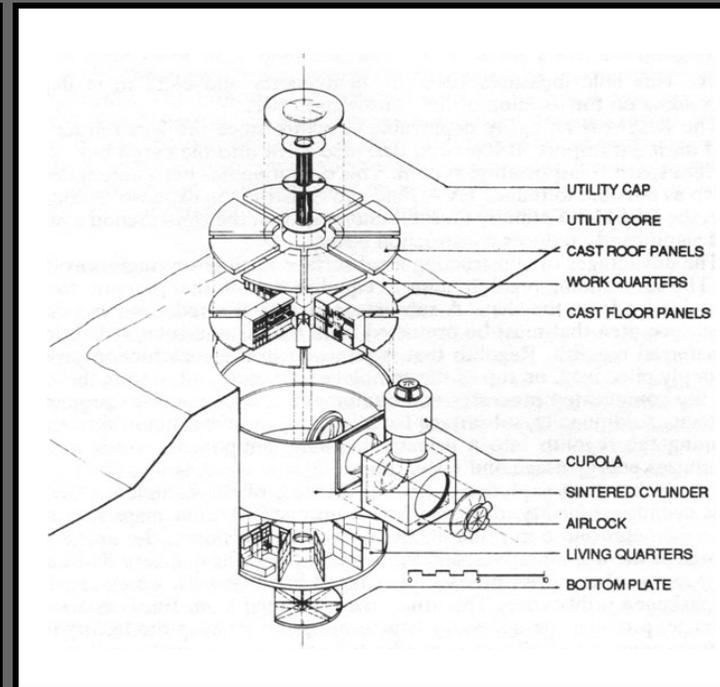
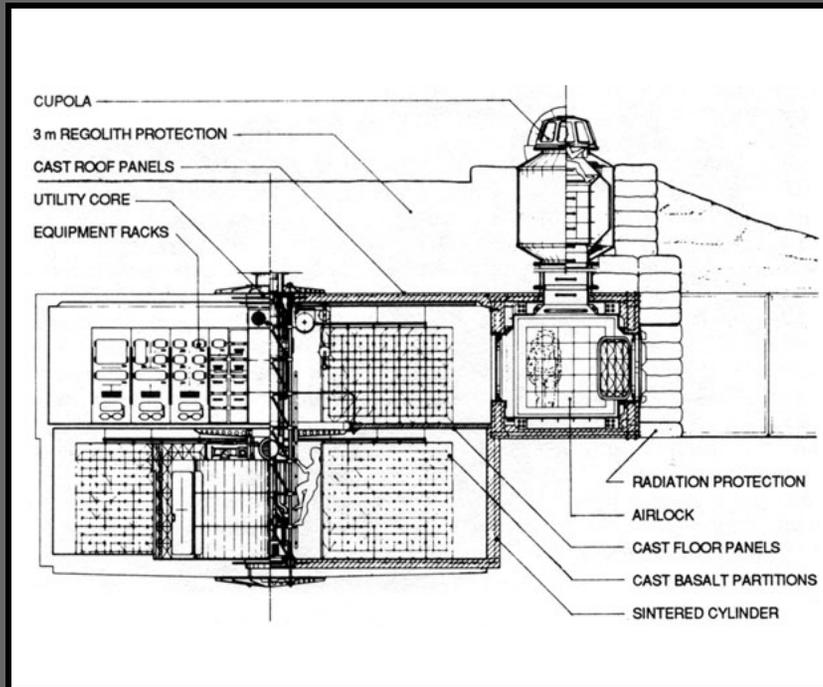


Space Applications

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**EARTHSCRAPERS**

**GOING UNDERGROUND**



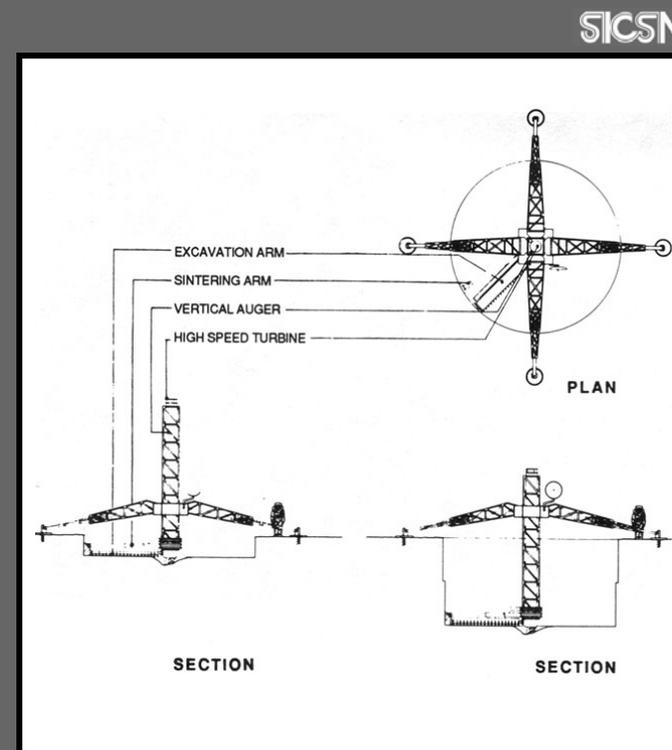
Space Applications

EARTHSCRAPERS

GOING UNDERGROUND

Proposed construction stages:

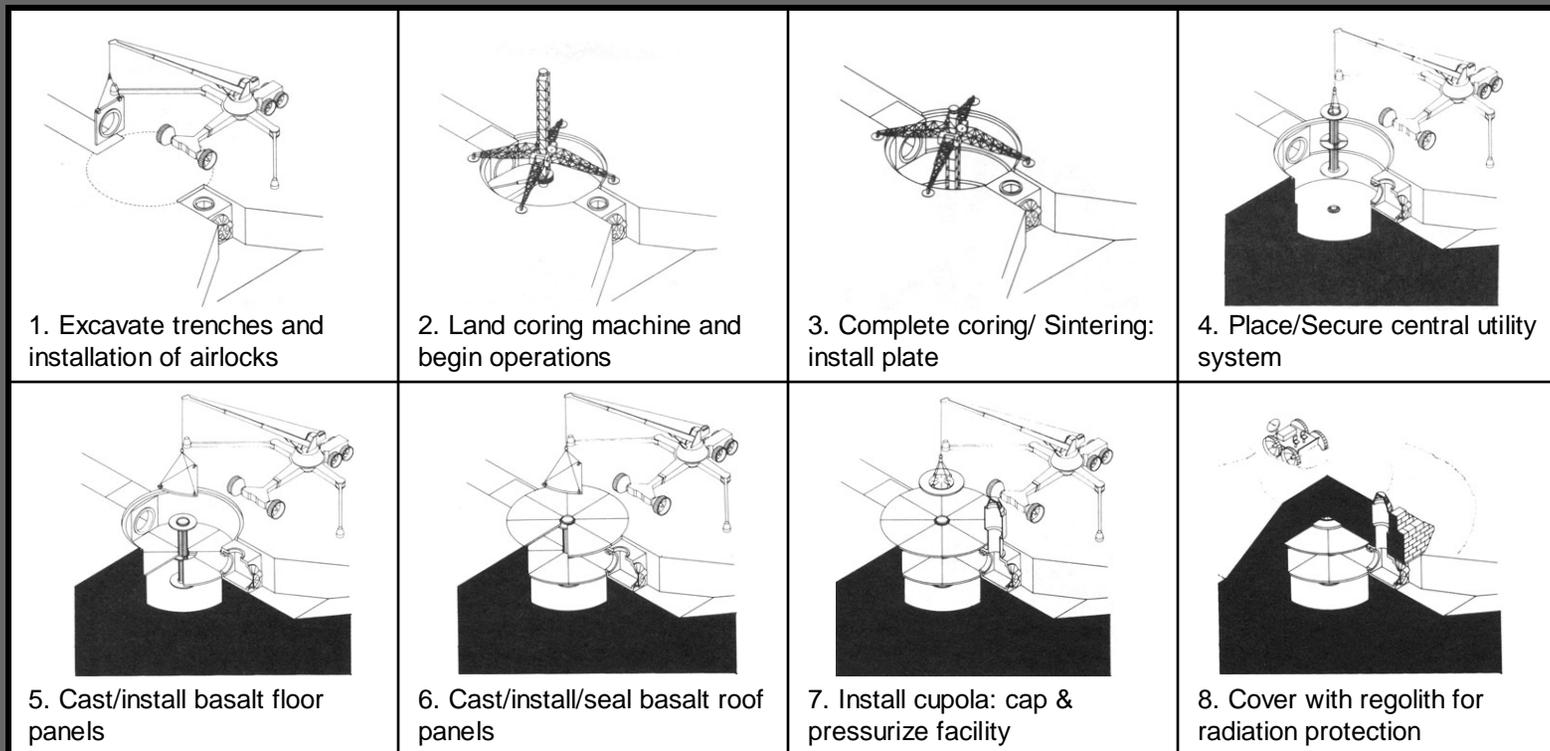
- Stage 1: An excavation auger with an excavation arm, microwave sintering element, and helical regolith removal screw is dispatched to the lunar surface.
- Stage 2: The excavation arm pivots around the helical screw shaft and excavates a core habitat volume. As this process occurs, the interior wall surface is sintered by the microwave device at the end of the sintering arm. Regolith that is excavated is transported by the screw and cast outside the cored area.
- Stage 3: Airlocks enclosures are cast of basalt along with habitat walls, floors, partitions and roof structures. Airlocks can be sealed by internal pressure membranes.
- Stage 4: Prefabricated elements are delivered to the site and incorporated into the structures, including cupolas, pressure hatches, utility systems and other equipment.



Space Applications

**EARTHSCRAPERS**

**GOING UNDERGROUND**



Space Applications

EARTHSCRAPERS

GOING UNDERGROUND

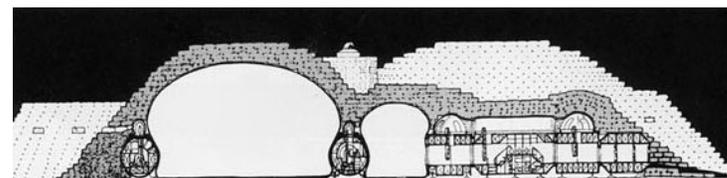


Just as soil coverings have sheltered early habitants on Earth, lunar and Mars soil (regolith) may one day protect future planetary explorers and settlers from hazardous space radiation.

- SICSA's "Project LEAP" concept would utilize bags of regolith to cover pressurized inflatable and hard modules:
  - The bag approach would enable steeper stacking with less material than loose particles (slope angle) and help control dust.



**SICSA's "Project LEAP" Lunar Concept**



**Section Through Site**



**Without Shielding**



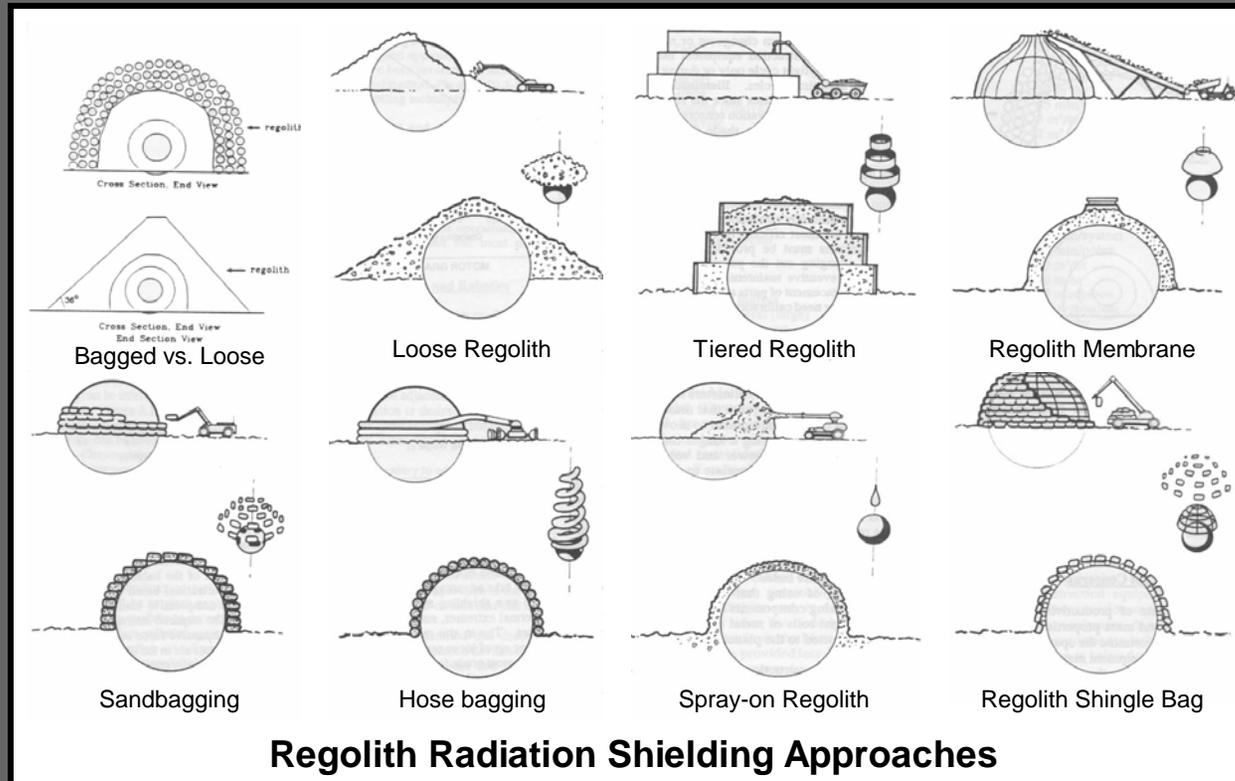
**With Shielding**

**Regolith for Radiation Protection**

**Space Applications**

**EARTHSCRAPERS**

**GOING UNDERGROUND**



Space Applications

EARTHSCRAPERS

GOING UNDERGROUND



Simple survival shelters built of natural materials have existed since the dawn of Man and continue to be constructed by military troops, outdoor enthusiasts, and explorers today.

- Such temporary refuges can take a wide variety of forms in response to the special needs, settings, and available construction resources. Some general planning considerations follow:
  - Wet sites require adequate drainage.
  - Combustible materials should be kept upwind from fires and smoke.
  - East-oriented entrances will admit warming rays of the morning sun, and fireplaces should orient wind to the back.



**Using Natural Materials**

**Survival Shelters**

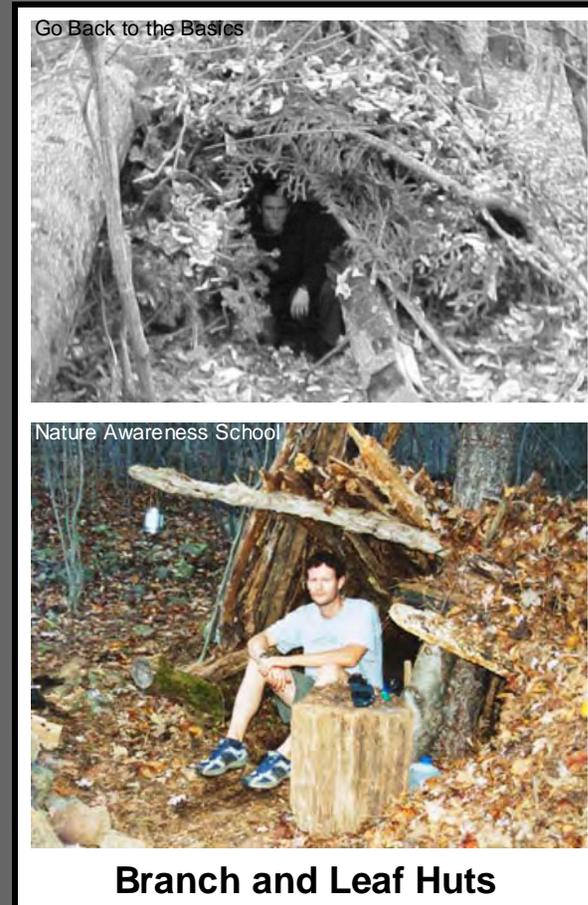
**EARTHSCRAPERS**

**SCAVENGED RESOURCES**



Good shelter design often adopts principles associated with wildlife, such as using natural materials and landscape conditions to the best advantage. Building “nests” of twigs and leaves, and finding shelter in caves, rock outcroppings, under logs, and in root networks are examples.

Shelters constructed of leafy branches provide insulating air spaces that help keep them warm even if the leaves are wet. Leaves used as doorways can also allow fresh air to enter and avoid unhealthy oxygen deficits during the night which can induce headaches and vomiting.0

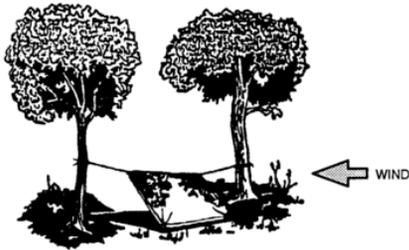


**Branch and Leaf Huts**

Survival Shelters

**EARTHSCRAPERS**

**SCAVENGED RESOURCES**



**Poncho Lean-To**



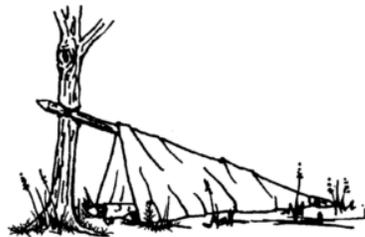
**Poncho Tent Using a Branch**



**No-Pole Teepee**



**Poncho Tent with A-Frame**



**One-Man Shelter**

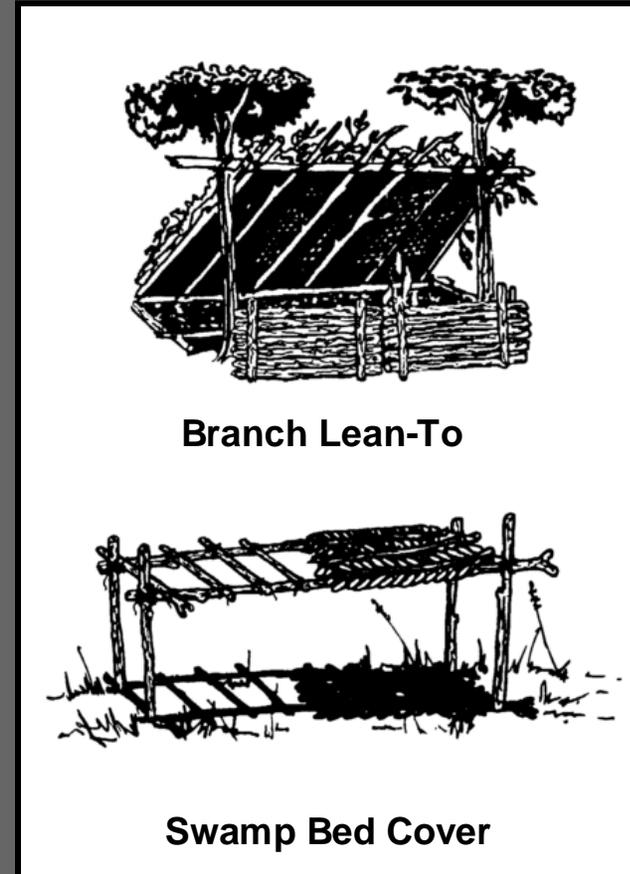
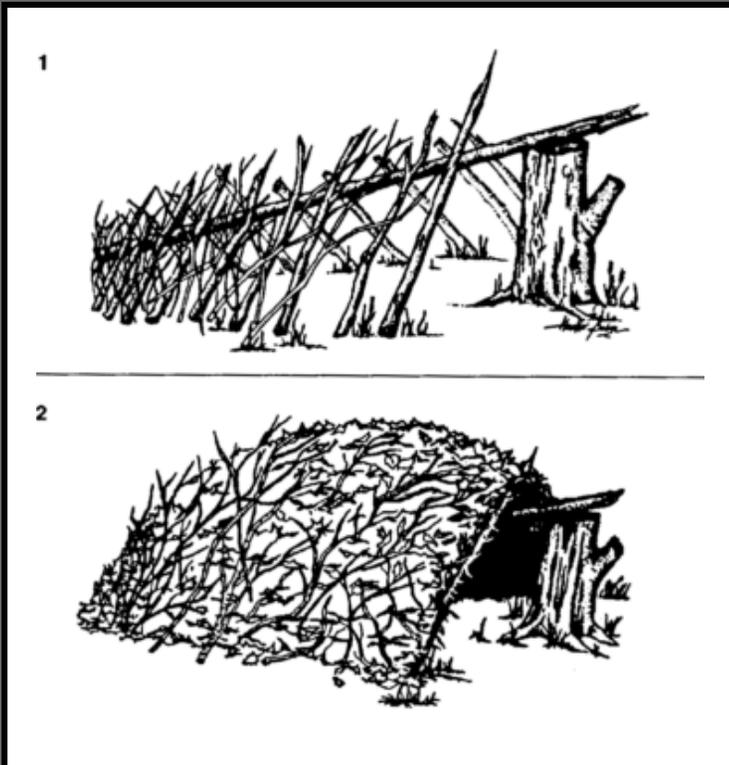


**One-Pole Teepee**

Survival Shelters

**EARTHSCRAPERS**

**SCAVENGED RESOURCES**



Survival Shelters

**EARTHSCRAPERS**

**SCAVENGED RESOURCES**

Aircav



- 1 Lay out parachute and cut six gores of material.
- 2 Starting from one side, make two folds each, one gore in width, yielding a base of three thicknesses of material.
- 3 Suspend hammock between two trees with the skirt higher than the apex. \* Place a spreader bar between the lines at the skirt and lace it to the skirt. Stretch an awning line between the two trees.
- 4 Drape the remaining three gores over the awning line and tuck the sixth gore into the shelter. Prop forked branches under the spreader bar to stabilize the shelter.

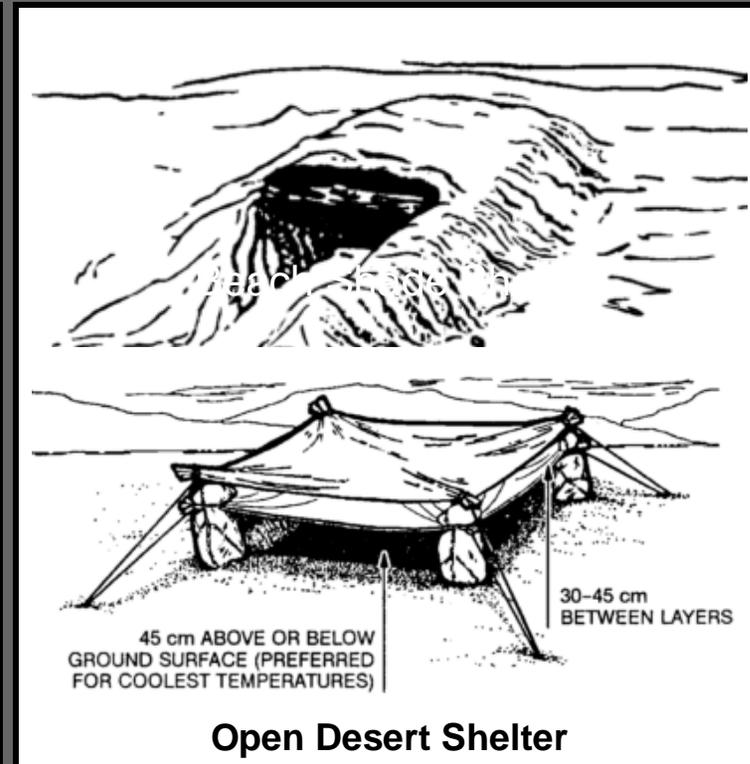
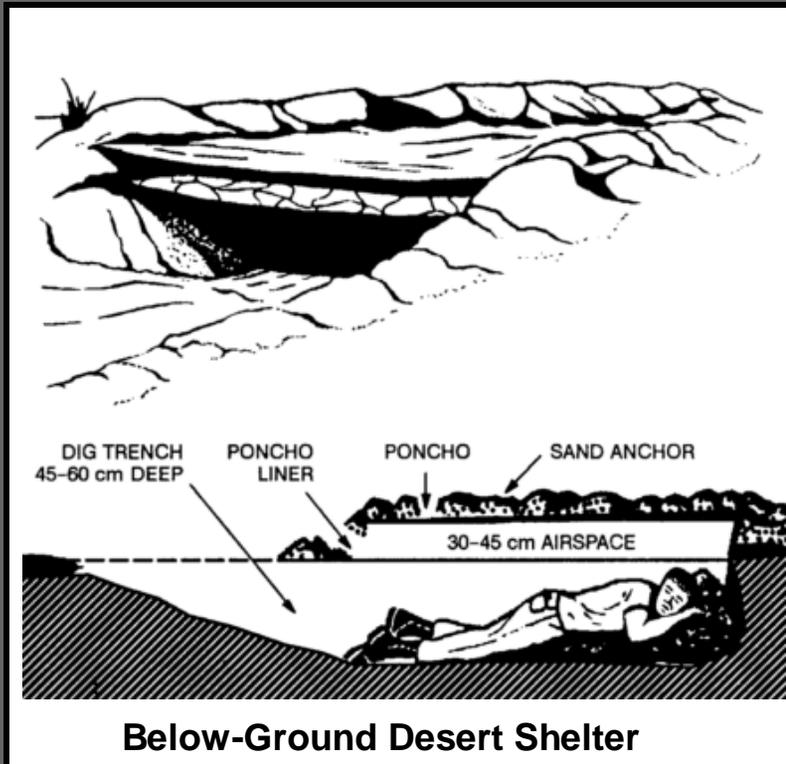
\* An alternate and more stable configuration would be to tie each side of the skirt to a separate tree. However, this configuration of three trees could be difficult to find.

**Parachute Hammock**

Survival Shelters

EARTHSCRAPERS

SCAVENGED RESOURCES



Survival Shelters

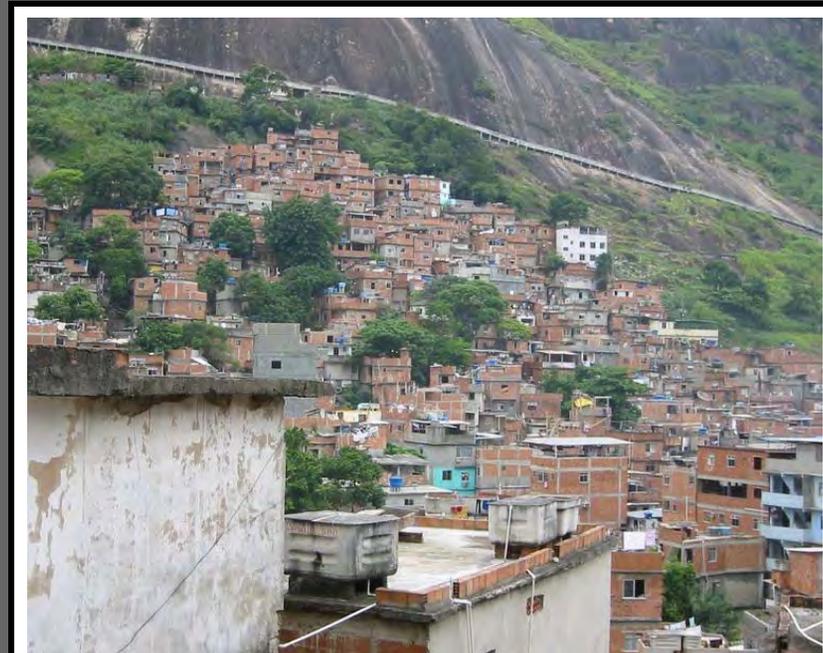
**EARTHSCRAPERS**

**SCAVENGED RESOURCES**



Survival shelters are an ever-present necessity for large impoverished population groups throughout the world, such as those who live in the Favela slums of Brazilian cities:

- There, the only architect is the spirit of invention driven by need and deprivation:
  - Makeshift dwellings are constructed from all sorts of materials, including discarded wood, scrap metal, bricks, fabrics, and trash.
  - Unless “borrowed” through illegal connections, water and electricity do not exist.
  - A lack of food refrigeration, sanitation, and insulation protection from harsh weather presents health hazards for inhabitants of all ages.



**Favela Slum in Brazil**

Urban Survival

**EARTHSCRAPERS**

**SCAVENGED RESOURCES**



A primary lesson of “slum shelters” is that all available materials can and must be used resourcefully if that is all you have.

This lesson can teach us to appreciate that all societies must learn to use resources more wisely if they are to enjoy long-term survival.



Habitat for Humanity



Chenoa Stock



Knoxville News Sentinel

### Urban Survival

## EARTHSCRAPERS

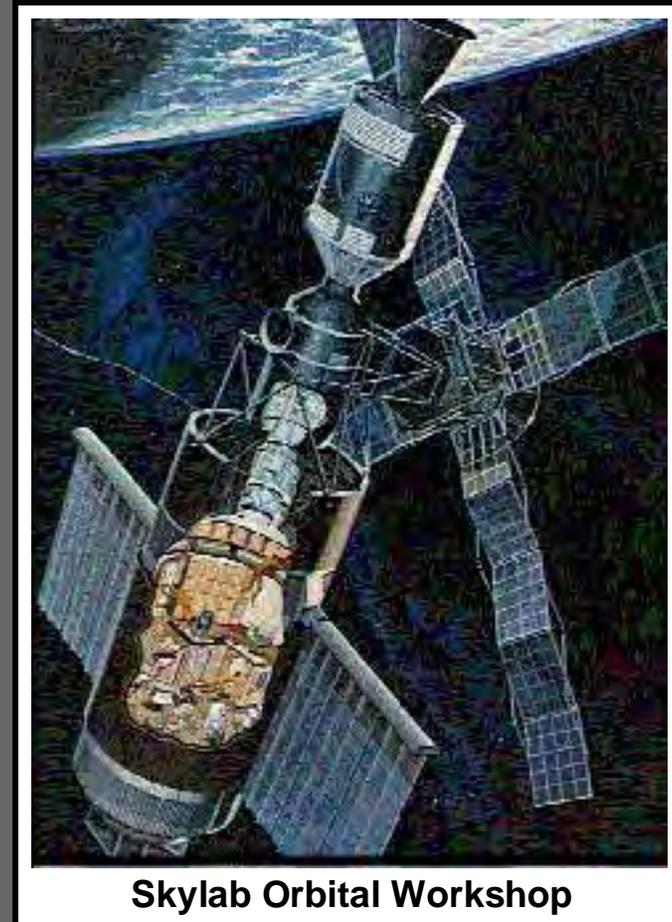
## SCAVENGED RESOURCES



B-24  
NASA

The US Skylab space station Orbital Workshop module was arguably the most substantial scavenged resource shelter in human history

- The 118 ft long × 22 ft diameter pressure vessel was developed using the third stage hydrogen tank from the Saturn V rocket (also used for the second stage of the smaller Saturn IB) to reduce costs:
  - Providing 9,950 ft<sup>3</sup> of habitable volume, the module served as the first and longest-ever single space environment, housing three separate three-person crews.
  - Launches to Low Earth Orbit (LEO) on May 14, 1973, the facility was operational for about nine months (from May 25 through February 8, 1974).



**Skylab Orbital Workshop**

Space Applications

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**EARTHSCRAPERS**

**SCAVENGED RESOURCES**



Rammed-earth construction is an age-old technique that utilizes raw soils to create strong, fire-resistant structures.

- Walls in China, Africa, and even cold/wet northern Europe have lasted several hundred years, and houses built in the late 1700s and early 1800s still exist throughout the US:
  - They are most common in arid regions where wood is scarce.
  - This building approach has witnessed a revival in recent years due to advantages of simple materials and construction methods.



Jenny Edwards



Wilson Graham

## Rammed-Earth Structures

**EARTHSCRAPERS**

**EARTHWORKS**



Rammed-earth walls are built by tamping a mixture of raw soil and a stabilizer into forms:

- Sometimes sand, gravel, and clay are also added:
  - Traditional stabilizers of the past were lime or animal blood, but a 3% addition of Portland cement is the modern choice.
  - The soil is dumped into forms in lifts up to 7" – 8", and then is pounded down to 4" – 5" by pneumatic tampers.
  - The forms can then be removed immediately, and the walls become stronger with each passing day until dry.
  - Outside surfaces exposed to weather must then be water-sealed.



**Rammed-Earth Construction**

**Rammed-Earth Structures**

**EARTHSCRAPERS**

**EARTHWORKS**



**Construction Process**

**Rammed-Earth Structures**

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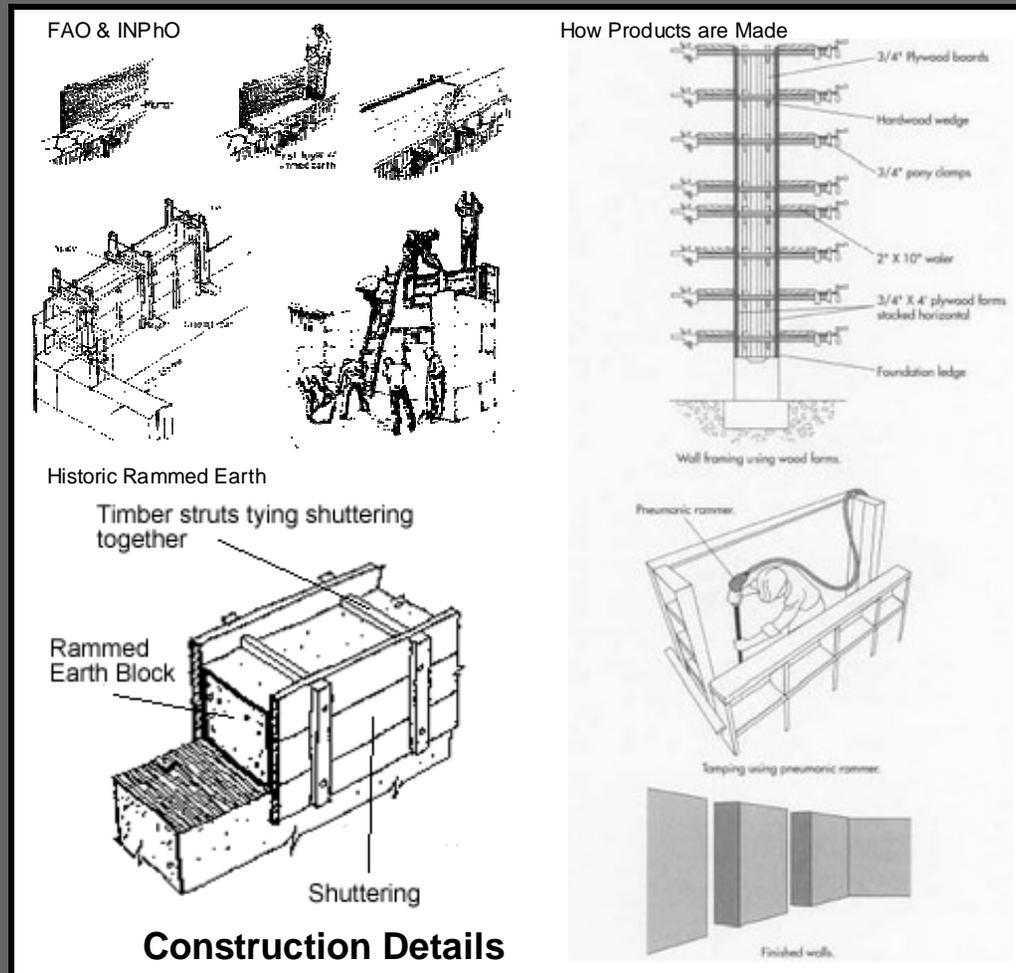
**EARTHSCRAPERS**

**EARTHWORKS**



Rammed-earth walls are constructed upon conventional footings and/or a re-enforced concrete base along with extra ground insulation provided by a horizontal styrofoam layer.

The walls have excellent thermal mass qualities to heat up slowly during the day and release stored heat at night, but like brick and concrete, are poor insulators, and require insulation in cold climates.



Rammed-Earth Structures

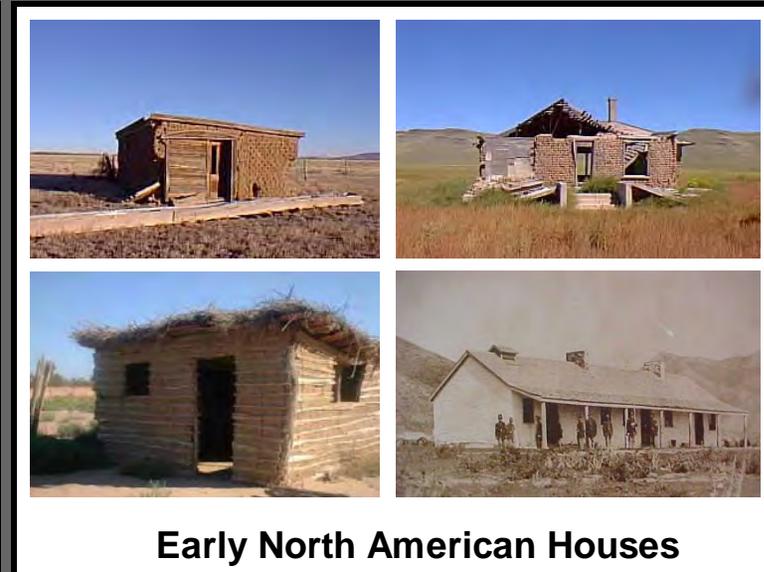
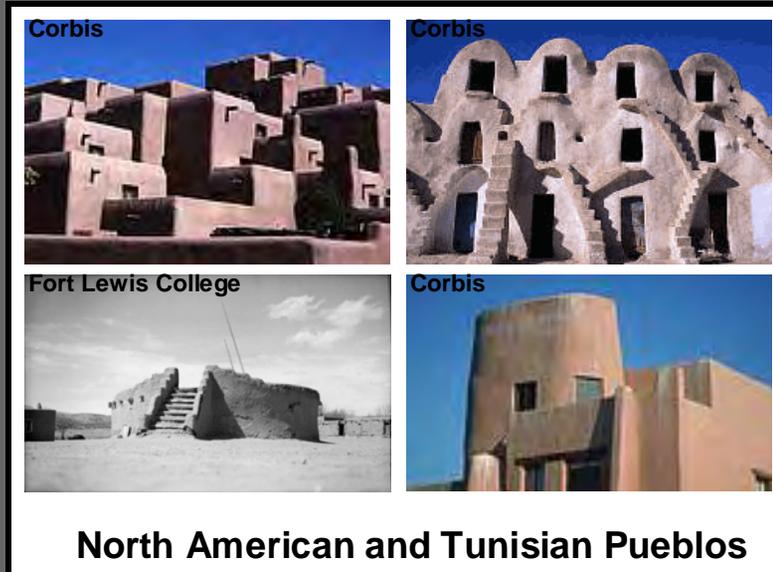
EARTHSCRAPERS

EARTHWORKS



Adobe brick-making techniques were introduced into the Americas by Spaniards in the 16th century. Many used animal dung rather than straw as a binder because it offered the same advantages of stability, even drying, and insect resistance.

Adobe structures offer a number of important benefits. They are simple to construct by unskilled labor, use common and abundant materials, are strong and versatile, and offer significant heat reservoirs for heating and cooling.



**EARTHSCRAPERS**

**EARTHWORKS**



Adobe structures are extremely durable and account for the oldest existing buildings on our planet.

- They were common throughout the Middle East and Spain:
  - The walls were constructed of bricks made of sandy clay and straw, animal dung, or other organic materials shaped into wooden forms and dried in the sun.
  - Since these structures have a relatively dense thermal mass to retain heat during the day and release it at night, they are best suited for arid climates.
  - They are less useful in temperate climates due to heat leaking into the ground and brick walls.



**House in Syria**



**Houses in Yemen**



**Adobe Buildings in Iran**



**Home in Madagascar**

**International Applications**

**Adobe Structures**

**EARTHSCRAPERS**

**EARTHWORKS**



Adobe bricks range in size from ordinary baked types (“adobes”) to some that range from 1 -2 yards long (“adobines”).

- The manufacturing process is very simple:
  - Clay, straw, and water are first mixed to create a paste.
  - The mix is placed in open frames of the desired size and allowed to dry in the sun for a few hours.
  - The bricks are then removed from the molding frames and turned on an edge to slowly finish drying in the shade to avoid cracking.



**Brick-Making Process**

Adobe Structures

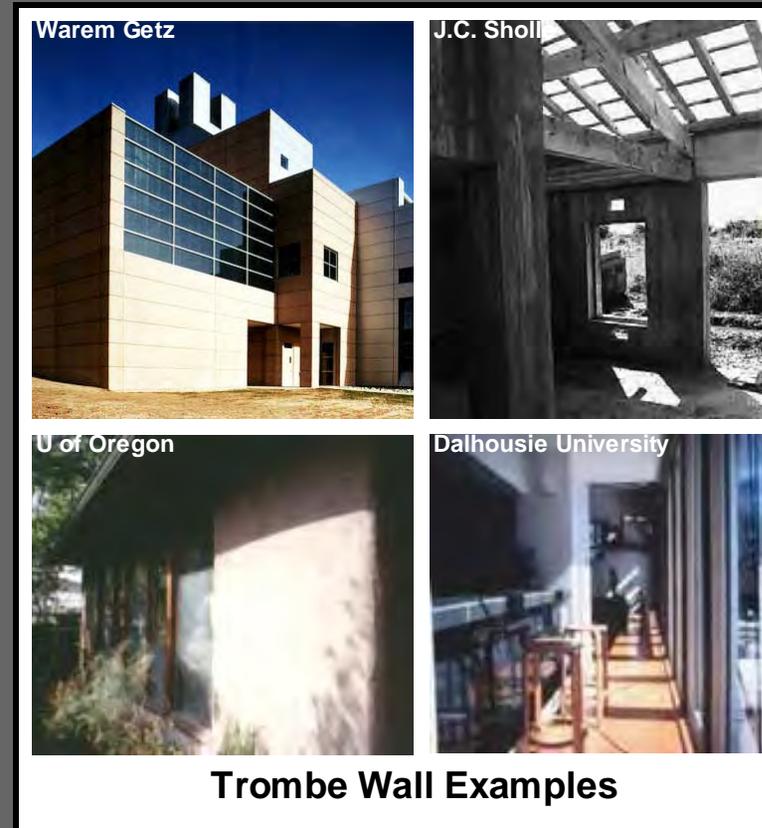
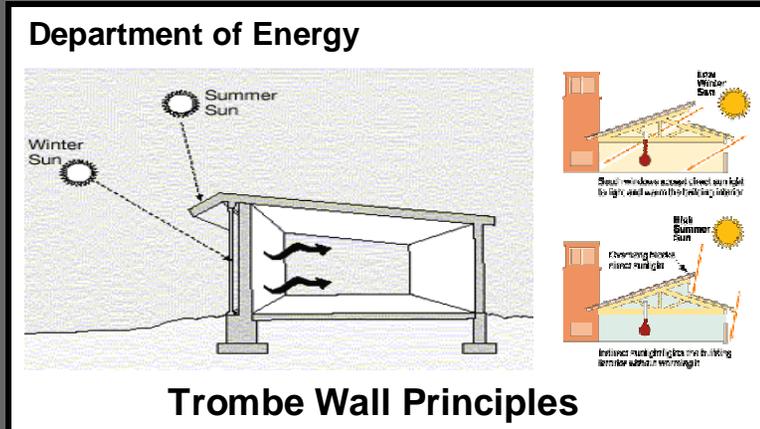
**EARTHSCRAPERS**

**EARTHWORKS**



South-facing adobe walls in the Northern Hemisphere may be left un-insulated to moderate heating and cooling. They should be thick enough to remain cool on the inside during the heat of day, yet thin enough to transfer heat out at night.

Wall exteriors can be covered with glass to increase heat collection. In passive solar buildings this is called a "Trombe" wall.



Adobe Structures

**EARTHSCRAPERS**

**EARTHWORKS**



The Cal-Earth Institute in Hesperia, California, an educational program of the Geltaftan Foundation, has been designing and building “eco-dome” houses.

- The approach pumps various mixes of particulate material including earth, concrete, and recycled substances into long, tubular bags.
  - The fill material becomes self-supporting when formed into blocks by the tubing bags.
  - Barbed wire is used to attach stacked layers of bags together top-to-bottom and end-to-end.
  - The barbed wire creates tensile resistance between bag layers, and also transfers lateral shear stresses.
  - Additional concrete added to the mix enables curved, arched, and domed forms to be created.

Nader Khalili

B-33  
Cal-Earth Institute



**Eco-Dome House Construction**

**Sandbag Superadobe Structures**

**EARTHSCRAPERS**

**EARTHWORKS**

The sandbag “superadobe” construction approach applies a basic concept that has been used for centuries to build structures such as temporary dikes and protective walls in combat zones.

- These former applications were limited to low, flat structures due to a lack of tensile capabilities:
  - The addition of barbed wire for tensile benefits and shear transfer, and concrete for strength, make it possible to create curved, arched, or dome forms.
  - Sandbag superadobe structures built upon “floating ring” foundations are also highly earthquake resistant, enabling the buildings to slide across the ground as monolithic elements.

Nader Khalili

Cal-Earth Institute



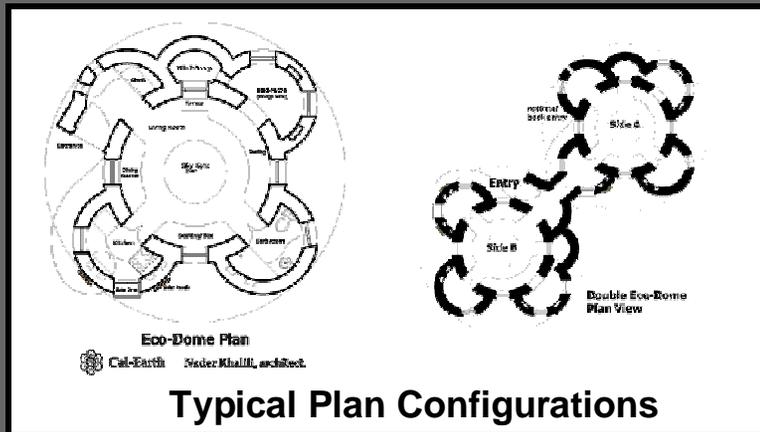
Sandbag Superadobe Structures

**EARTHSCRAPERS**

**EARTHWORKS**



Typical eco-dome houses provide a central room with a skylight on top, and four smaller dome rooms (two sleeping areas, a bathroom, and kitchen). Larger houses can be created by connecting individual homes together.



Sandbag Superadobe Structures



Sandbag superadobe construction is strong and termite-proof, enabling it also to be used to create foundations (poured into tubing forms) and load-bearing partition walls. Exterior and interior surfaces can be covered with stucco and other finishing materials.



**Vaulted House Application**

**Nader Khalili**

**Cal-Earth Institute**



**Exterior and Interior Finishes**

**Sandbag Superadobe Structures**

**EARTHSCRAPERS**

**EARTHWORKS**



Nader Khalili

CERAMIC HOUSES

The “geltaftan” (fired structure) system was advanced by architect Nader Khalili to fire and bake adobe earth-clay block buildings in place, using the structure as its own kiln. It can then be glazed like a typical ceramic vessel.

- The process involves stacking sun-dried adobe bricks in a circular tower form and introducing fire from below:
  - A 3/8 “ thick mud plaster covering outside the perimeter works as the kiln.
  - Heat from inside fire penetrates to the outside and bakes all the bricks. (Since no mortar is used, the heat reaches the outside plaster cover.)
  - Glazing can be applied and fired after the structure is “baked”.

**Geltaftan System Construction**

Fired Ceramic Structures

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**EARTHSCRAPERS****EARTHWORKS**



The geltaftan construction process applies ancient earth-clay kiln design principles that have been used throughout the world, including Iran and neighboring countries, China, Japan, Korea, Nigeria, and bread ovens of native Americans.

- Traditional Persian “kaval” kilns of the type that inspired Khalili’s approach were used to fire underground aqueduct (“ganat”) pipe sections:
  - These kilns looked much like old village houses with long barrel-vault rooms. (Typical kilns were 22.5 ft long × 11.5 ft wide × 9.5 ft high.)
  - Originally constructed of adobe blocks and clay mortar, they became strong, durable ceramic structures after being fired.



Two-Room House Being Fired as a Unit



Homemade Kerosene Burner Used



Traditional Bread Oven Used in Iran

**Applying Ancient Kiln Design**

Fired Ceramic Structures

**EARTHSCRAPERS**

**EARTHWORKS**



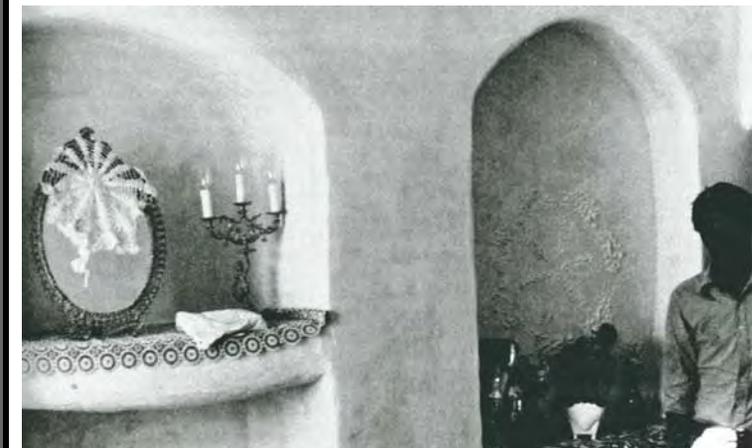
Khalili initially applied and demonstrated the geltaftan process to reconstruct some old adobe houses in the Iranian village of Ghaleh Mofid which were in very poor condition.

- The work was undertaken by local people using simple man-made burners for firing:
  - Existing doors and windows were removed, and mortar-less temporary partitions were built into the openings.
  - Clay pottery products were fired inside, along with the building structures.
  - Gravity-flow kerosene burners were fabricated out of two pieces of pipe welded together with an “air sandwich” between them (similar to homemade torches used by local blacksmiths).
  - Two barrels of kerosene oil on adjacent roofs provided fuel.

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Nader Khalili

CERAMIC HOUSES



**House Reconstruction by Owner**

Fired Ceramic Structures

**EARTHSCRAPERS**

**EARTHWORKS**



The reconstructed, fired houses in Ghaleh Mofid became hard as brick after being fired at several hundred degrees over about 24-hour periods.

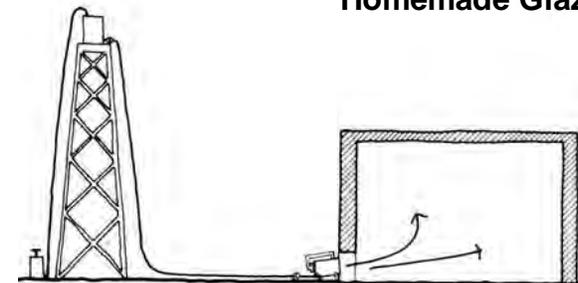
- The process involved the following general steps:
  - Provide necessary flues, and fill the space with whatever else is to be fired.
  - Position the burners in place.
  - Block door and window openings with adobe stacked without mortar.
  - Put a thin mud plaster on the outside and close any open joints to block fire. (This can be done while the fire is burning.)
  - Ignite the burners to fire the structure until “done”.
  - Glaze the interior as desired and re-fire.



Firing the Structure



Applying  
Homemade Glaze



Gravity-Flow Kerosene Heater

General Procedures

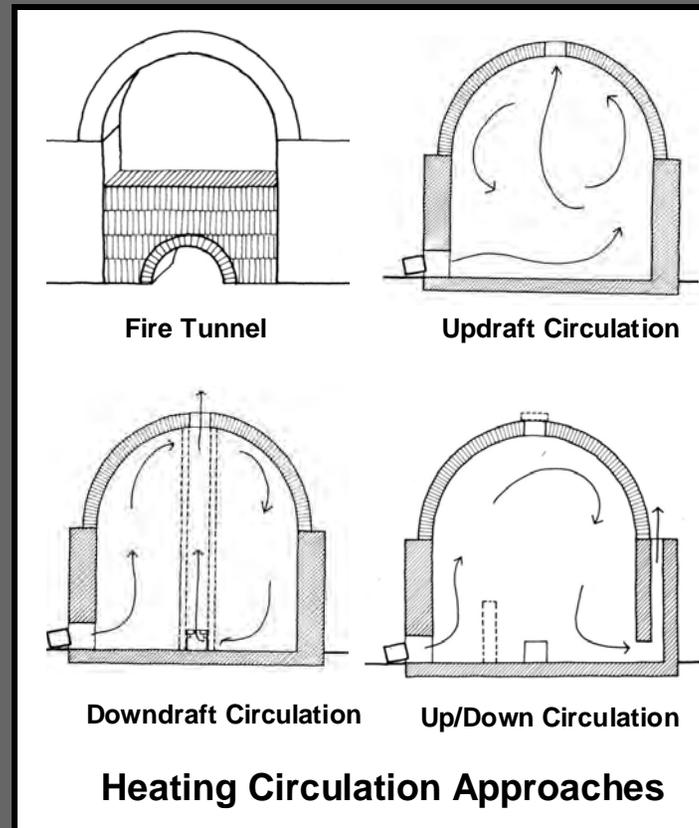
Fired Ceramic Structures

Three general approaches can be used to fire structures.

- Updraft circulation:
  - Fire below causes flame/gases to circulate upward.
  - For a small room, fire in front of a door and a hole in the roof will provide updraft.
- Downdraft circulation:
  - Similar to updraft except that instead of a hole on top, holes leading to a flue are located at the bottom.
  - Heat circulates up, around, and then down.
- Updraft/downdraft circulation:
  - A hole is left on top, and flues are placed on sides.
  - After several hours of low temperature firing, most vapor impurities escape out the top.
  - The top hole is then closed with an adobe block to reverse circulation and bake the foundation at a higher temperature.

Nader Khalili

CERAMIC HOUSES



Fired Ceramic Structures

**EARTHSCRAPERS**

**EARTHWORKS**

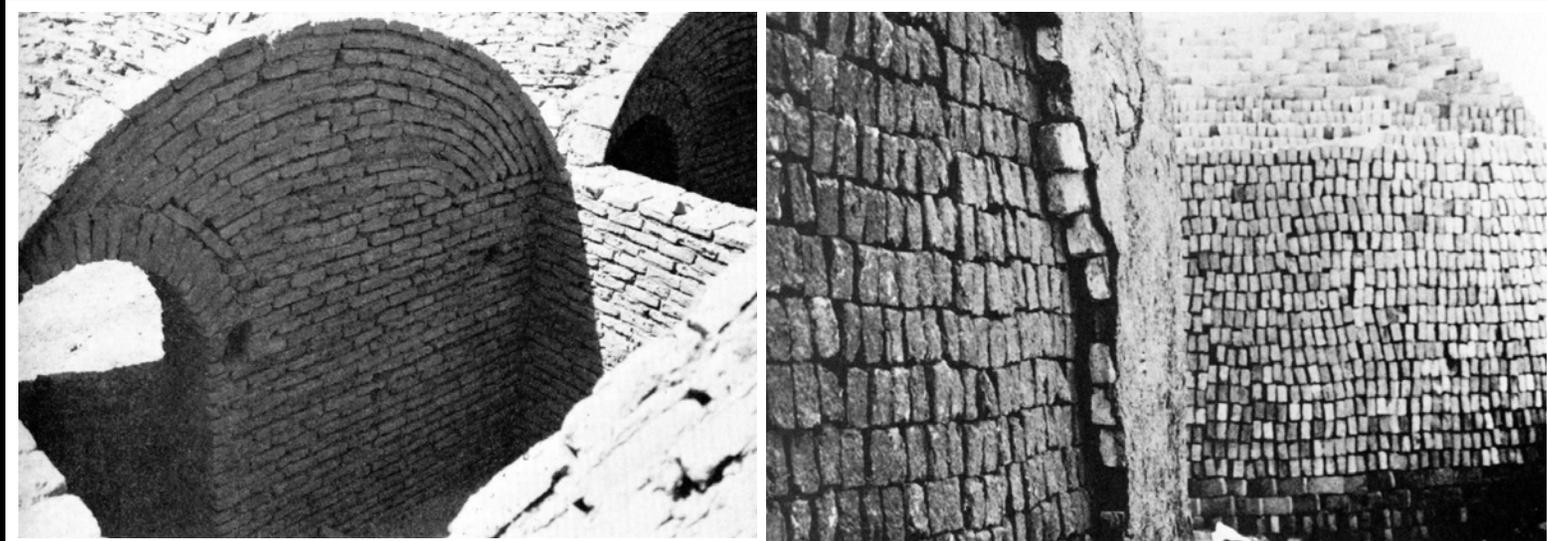


- Planning and implementation of the geltaftan process should consider some general requirements:
- Adobe-making must be scheduled according to regional weather conditions.
- Roofs should be plastered after (or during) firing to avoid cracks produced by steam.
- Large adobe cracks should be repaired before firing to prevent structural problems, while smaller ones can be fixed later.
- Walls and ceilings should be wet down after cooling to neutralize lime reaction to humidity.

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Nader Khalili

CERAMIC HOUSES



Special Planning and Implementation Considerations

Fired Ceramic Structures

EARTHSCRAPERS

EARTHWORKS



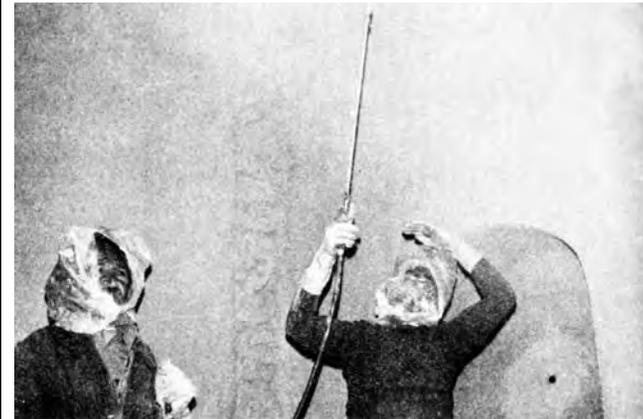
Interior clay surfaces can be fired with a great variety of glaze colors, designs, and textures, like pottery.

- Glazing involves brushing or spraying on powdered oxides mixed with water to produce a glass-like material for durability and beauty:
  - Sprayers can use simple bicycle pumps, and glaze can be created by grinding broken Coke bottles and adding a few oxides.
  - Salt glazing is also very inexpensive and beautiful, but produces poisonous chlorine gas when fired.
  - Salt glaze isn't used in conventional kilns because it glazes the kilns before the pottery, but this is actually an advantage for building applications.
  - It is advisable to leave some wall areas unglazed to allow the interior to “breathe”.

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Nader Khalili

CERAMIC HOUSES



**Glazing Interior Surfaces**

**Fired Ceramic Structures**

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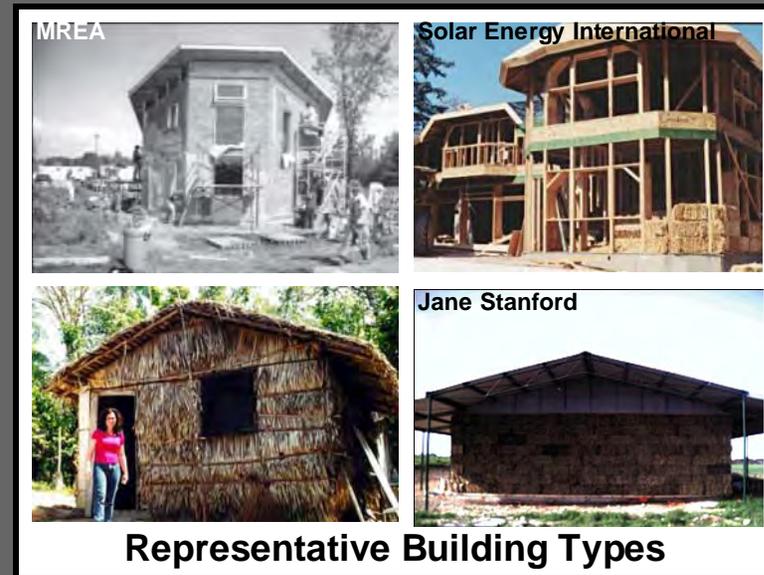
**EARTHSCRAPERS**

**EARTHWORKS**



The first straw bale buildings were constructed in the sand hills of Nebraska nearly 100 years ago.

- They are attracting renewed interest today for several reasons:
  - Straw is a renewable resource and an unwanted waste product of grain production. (Unlike hay which is used for feeding livestock, it is composed largely of cellulose, hemicellulose, lignin, and silica.)
  - Straw bales have high-insulative R-values comparable inch-for-inch thickness to fiberglass insulation batts.
  - Owner-built structures can cost as little as \$25 - \$50/ft<sup>2</sup> and be constructed quite rapidly.
  - The construction can be used to create simple or complex buildings up to three stories high resembling stone or adobe walls.



Straw Bale Structures

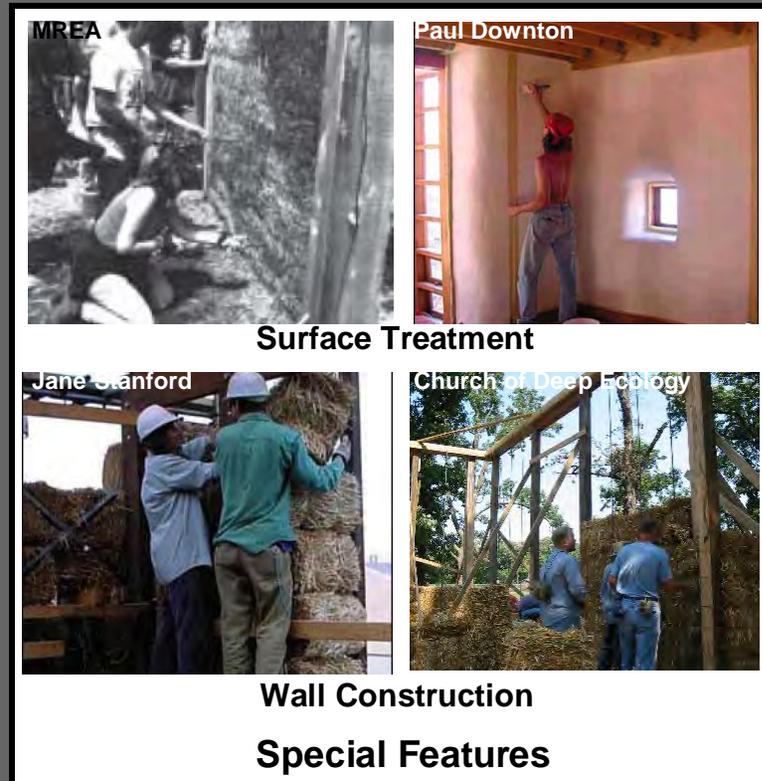
**EARTHSCRAPERS**

**ORGANIC CONSTRUCTIONS**



Dense packing of straw bales, in combination with plaster coating applied to exterior and interior wall surfaces, provides strength and resistance to fire/toxic smoke and vermin:

- Such structures have survived California brush fires that destroyed conventional buildings:
  - The compressed straw reduces available internal space for oxygen necessary for combustion, and plaster on both sides keeps ignition sources away
- Plaster surface coatings deter mice and insects:
  - Two or three coats are typically applied, including earthen sand/clay types, soft plasters which use lime or gypsum, or hard plasters using Portland/sand/lime mixes.
  - Various fibers can be added for extra strength.



**Surface Treatment**

**Wall Construction**

**Special Features**

**Straw Bale Structures**

**EARTHSCRAPERS**

**ORGANIC CONSTRUCTIONS**



There are two primary types of straw bale wall construction: load-bearing, and non-load-bearing:

- Load-bearing walls use the straw bales and plaster linings to carry the roof and lateral shear pressures:
  - This construction is best suited for small, simple buildings with few windows and door openings.
  - Each bale can withstand up to 15,000 lb loads, but since they compress, should be pre-compressed before plastering.
- Non-load-bearing walls have frames that carry loads, using straw bales for in-fill insulation:
  - Framing options include post and beam, post and header, and pole building design.
  - The framing adds cost, but enables roofs to be built to keep the straw dry during construction.



**Load Bearing Walls**

**Non-Load Bearing Walls**

**Construction Approaches**

**Straw Bale Structures**

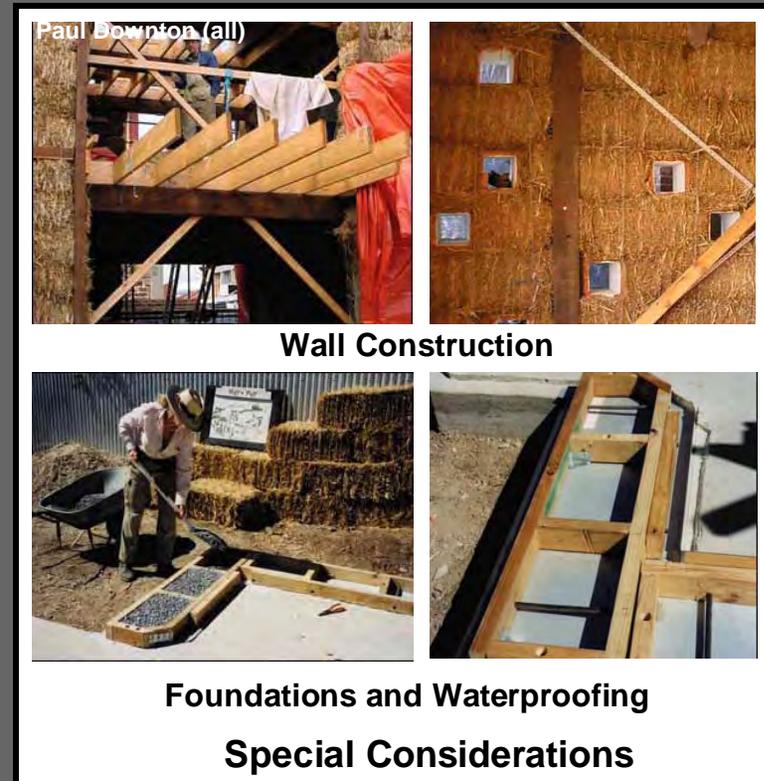
**EARTHSCRAPERS**

**ORGANIC CONSTRUCTIONS**



If protected from becoming water-logged, straw bale structures can last 100 years or more:

- Straw bales must be properly constructed and supported for durability:
  - As with conventional structures, footings are required, potentially including concrete strips/slabs, rubble trenches, or other types.
  - After being stacked in a staggered configuration, poultry netting is attached to the bales before the plaster is added to help secure them, add rigidity to the plastering process, and reinforce the plaster coat.
- Fungi can be a problem if the straw bales are exposed to too much water:
  - Bales should be covered during construction to keep moisture content below 15 percent.
  - A water barrier is required between the foundation and the first course of bales.

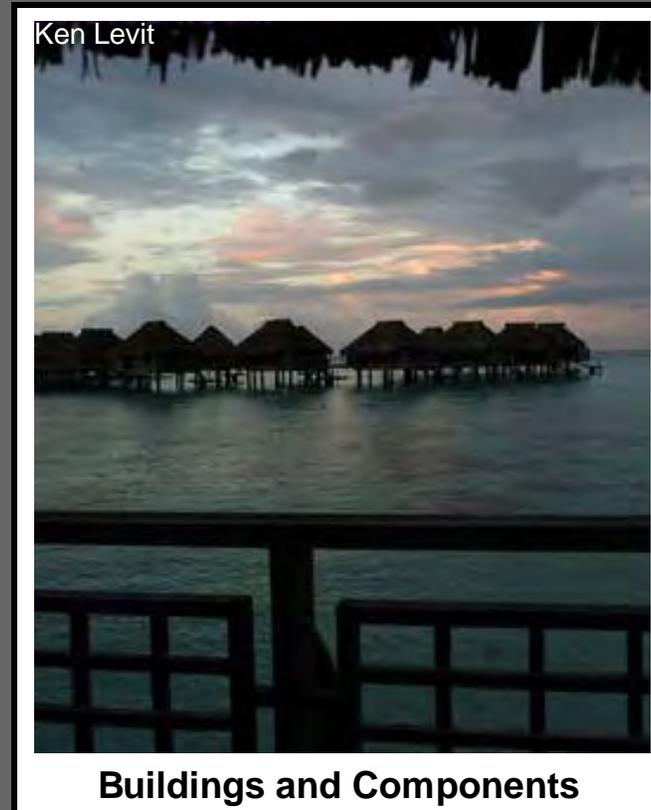


Straw Bale Structures



Bamboo has a long tradition for building construction in many parts of the world, particularly in tropical climates where it grows in larger diameters. These regions include South America, Africa and South Asia:

- The material offers many advantages:
  - It is very strong, with about twice the compressive strength as concrete, and roughly the same strength-to-weight ratio as steel in tension.
  - High elasticity and low mass offers excellent earthquake resistance for large structures.
  - It offers great versatility of use as a framework for other construction materials, as a component of plywood and composite beams, and for creating flooring, stair treads, molding and a variety of other products.



**Buildings and Components**

Bamboo Structures

**EARTHSCRAPERS**

**ORGANIC CONSTRUCTIONS**



The strength of bamboo is evident in applications for long-span bridges.

- Automobile bridges spanning up to 150 ft have been constructed by Jorg Stann in Columbia

Jorg Stann



**Long Span Applications**



**Bamboo Bridges**

**Bamboo Structures**

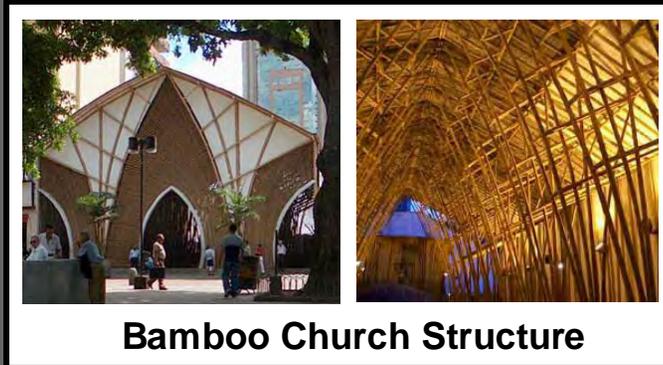
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**ORGANIC CONSTRUCTIONS**

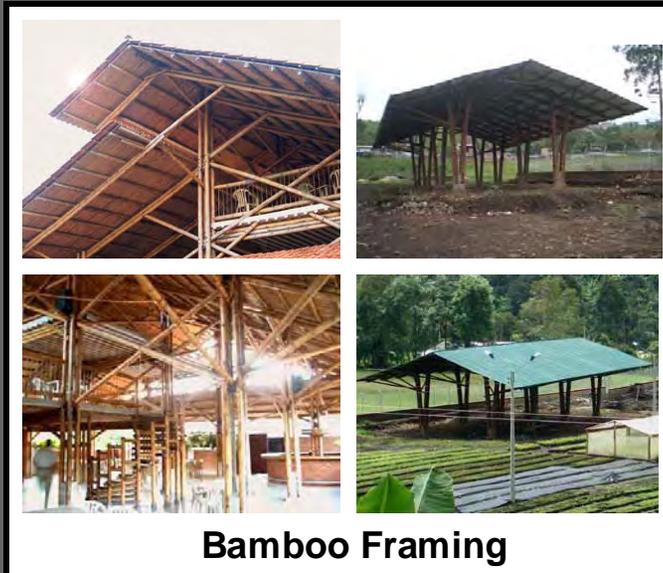
Simon Velez



**Bamboo Roof Structures**



**Bamboo Church Structure**



**Bamboo Framing**

**Bamboo Structures**

**EARTHSCRAPERS**

**ORGANIC CONSTRUCTIONS**



More than a billion people live in bamboo houses.

- In some regions it constitutes the main construction material:
  - Approximately 70% of the population in Bangladesh lives in houses partly or entirely made of bamboo.
  - Bamboo is becoming popular in Hawaii for owners who can well afford concrete and timber buildings. (Many of these homes are being prefabricated in Vietnam.)



**Bamboo House in Hawaii**



**An Ageless Approach**

**Bamboo Structures**

**EARTHSCRAPERS**

**ORGANIC CONSTRUCTIONS**

Bamboo is one of the most versatile and environmentally-sustainable materials.

- Uses include, fences, scaffolding, interior surfaces, and a wide variety of commercial products:
  - It is sometimes used in combination with earth materials, such as clay, to create more permanent dwellings.
  - Floor surfaces made of bamboo are harder than standard oak, yet cost about the same or less.



**Austrian Bicycle**



**Bamboo/Clay House**



**Scaffolding**



**Fences**



**Floor Surfaces**



**Stairways**

**Bamboo Structures**

**EARTHSCRAPERS**

**ORGANIC CONSTRUCTIONS**



Although very broadly used in tropical areas, some special limitations must be recognized:

- Applications should consider factors which will limit applications and attributes:
  - Bamboo performs much like hardwood and structural fir lumber, but splits and bleaches after a few years of exposure to strong sunlight.
  - It is even less durable in wet climates, but can be preserved indefinitely for indoor uses.
  - Untreated bamboo is vulnerable to powder post beetles and fungal attacks, but these problems can be reduced through heat curing, and boron introduced using a vacuum pressure method.
  - Since its strength comes from integral structure, members can't be joined together using many wood construction techniques.



**Special Considerations**

**Bamboo Structures**

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**EARTHSCRAPERS**

**ORGANIC CONSTRUCTIONS**



Thatched roofs over pole frame structures have provided a natural and traditional compliment to bamboo, earth and stone shelters throughout human history.

- Many cultures have adapted these building systems to their local resources, climates, lifestyle needs and creative inspirations:
  - Thatched roof construction utilizes abundant and easily replaceable plant materials.
  - Bamboo frames used to support the thatch can utilize full canes, halved canes, woven laths and ties.
  - A major drawback to thatched roof use is vulnerability to fires, a circumstance which is causing them to be banned for some or all applications in many places.



**Thatched Roof in Japan**

**Bamboo Structures**

**EARTHSCRAPERS**

**ORGANIC CONSTRUCTIONS**



**Bamboo Structures**

**EARTHSCRAPERS**

**ORGANIC CONSTRUCTIONS**



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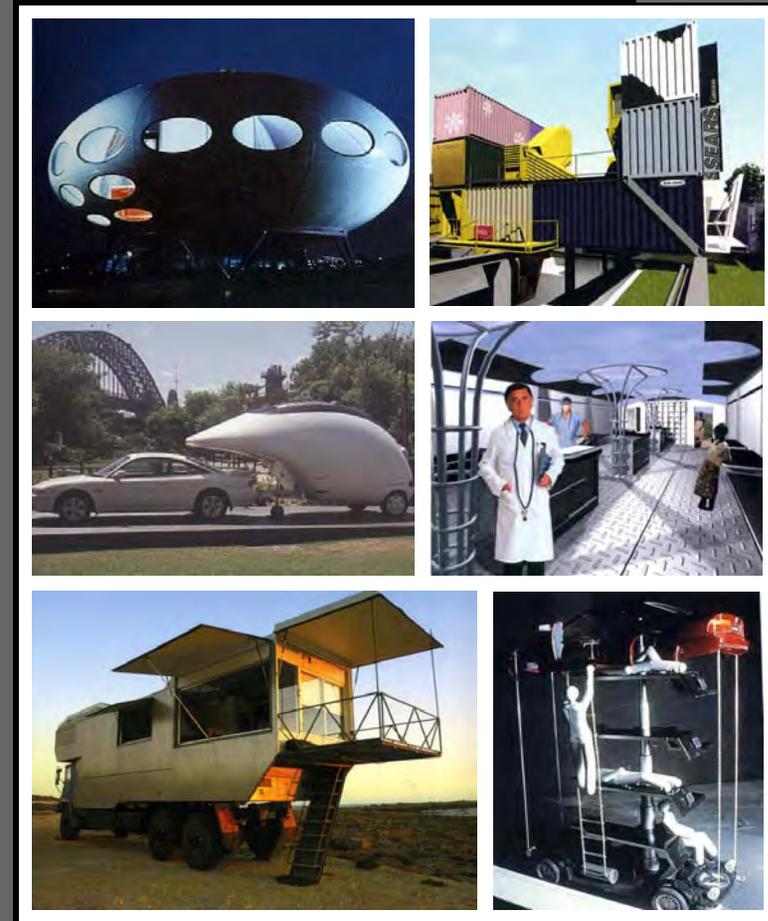


## SECTION C : MODULAR UNITS

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Modular units are hard-walled structures that typically incorporate pre-integrated utility and equipment systems and are designed to be carried or towed to sites by powered vehicles. Some variations can be attached together or stacked to create complexes, and some can be expanded through special articulating or add-on features.

- Cargo transport units include:
  - Fixed-volume types
  - Expandable-volume types
- Towable elements include:
  - Fixed-volume types
  - Expandable-volume types
- Self-transporting elements include:
  - Fixed-volume types
  - Expandable-volume types



## MODULAR UNITS

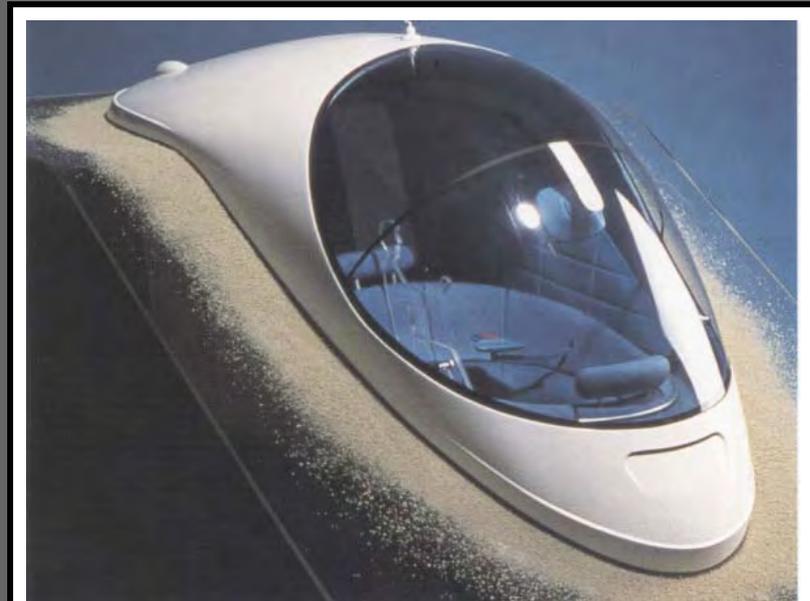
## CARGO, TOWED AND SELF-TRANSPORTING

Jan Kaplicky  
& David Nixon

FUTURE SYSTEMS

The Drop dwelling was designed for the 1989 Biennale in Nagoya to be installed as a complete unit with minimal site preparation:

- Construction would utilize two semi-monocoque shells comprised of ribs and spars welded to metal skin layers with foam insulation pumped in between.
- Each unit would have a large operable canopy of electro-photo chromatic glass shaded by horizontal louvers.
- Incoming air would be conditioned by a simple duct/slot system using an air-cooled reversible heat pump discharged through the floor and over the canopy surface.



**The Drop Concept**

Fixed- Volume Types

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**MODULAR UNITS**

**CARGO TRANSPORT**



During the late 1960's, a variety of "futuristic" portable pods were proposed, often constructed of self-supporting shells made of reinforced polyester plastic. Jean Maneval's Six-Shell Bubble House and Matti Suuronen's Futuro House are examples.

**Jean Maneval**

**MOVE HOUSE**



**Six-Shell Bubble House**

**Matti Suuronen**

**MOVE HOUSE**



**Futuro House**

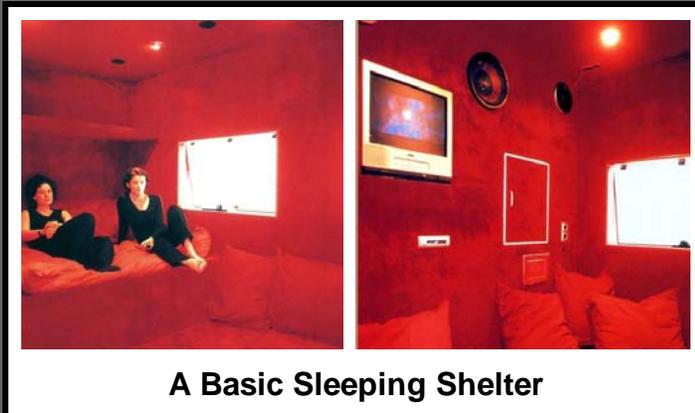
**Fixed- Volume Types**

**MODULAR UNITS**

**CARGO TRANSPORT**



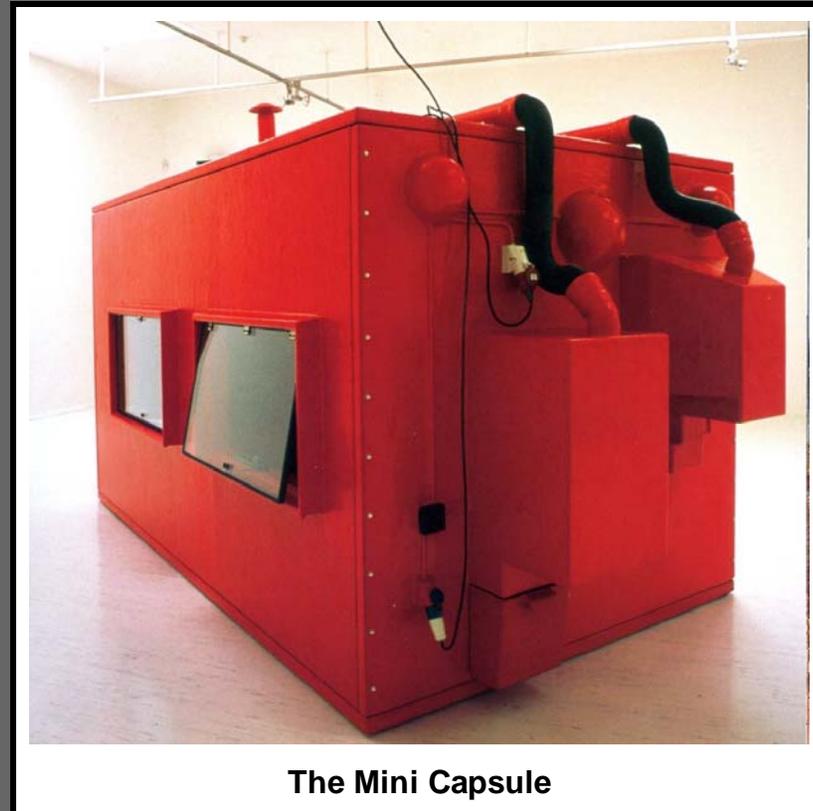
Atelier van Lieshout (ATL), a Rotterdam, Netherlands art, architecture and design firm, has developed a variety of portable buildings including a mobile power plant and restaurants. ATL's Mini Capsule is a modular room fitted with a bed, lamp, window, clothing hooks and an electrical outlet. (Toilets, sinks and showers are not provided.)



**A Basic Sleeping Shelter**

Atelier van Lieshout

MOVE HOUSE



**The Mini Capsule**

Fixed- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**

Atelier van Lieshout

MOVE HOUSE



**Stacked Sleeping Units**



**The Mini Capsule**

Fixed- Volume Types

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**MODULAR UNITS**

**CARGO TRANSPORT**

**PREFAB**

International Standardization Organization (ISO) shipping containers used for intermodal transportation can be used for creating a variety of shelter applications:

- Readily transportable by ship, train or truck, these containers are watertight and able to withstand large stresses associated with shipping, high winds and earthquakes.
- Construction options include steel and aluminum types, some with walls with skins over lightweight cores of other materials.
- Shelter design variations include containers that are used separately, attached end-to-end or side-to-side with removable walls to provide larger contiguous floor areas, and some which are stackable to create multi-storey habitats.



**ISO Shipping Container**

**Fixed- Volume Types**

---

**MODULAR UNITS**

**CARGO TRANSPORT**



Modified ISO shipping containers have been adapted to provide stable indoor environments to support military habitat functions. Examples include the NAVAIR, Marine Corps Shelter and the GMS-459:

- The shelters can be easily transported using helicopters or trailers in a manner applied to carry equipment and supplies to remote sites.
- Basic construction is comprised of aluminum skins over a core of rigid closed-cell foam:
  - Aluminum structural members within the panels offer added strength and provide locations for mounting equipment using Rivnut-type hardware.
  - End bands and base frames are fabricated from steel to resist impact loads.
  - Internal panels are made of aluminum skins over honeycomb cores.
- Some variants are equipped with removable ends and sidewalls, and EMI-shielded versions can provide protection up to 60dB.



**ISO Military Shelters**

**Fixed- Volume Types**

**MODULAR UNITS**

**CARGO TRANSPORT**

Many military and commercial field operations place personnel in harsh environments over long periods of time:

- Difficult site access to such areas in combination with limitations on construction equipment and schedules often preclude conventional building approaches:
  - ISO shelters afford a means to transport and deploy basic accommodations for substantial numbers of people in a short period of time.
  - Such shelters can provide for essential climate-control and hygiene/sanitation needs with reasonable comfort.
- A significant benefit of ISO shelters is their ability to be complexed in different ways:
  - They can be connected together at doorways via special butting kits that provide environmental seals.
  - Multiple side-removable shelters can be joined together to provide larger interior spaces.
  - The units can be stacked to create multi-storey complexes connected by standard stair elements.

## GICHNER SHELTER SYSTEMS



**Stacked ISO Complexing Approach**

Fixed- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**



## GICHNER SHELTER SYSTEMS

### Berthing Shelters

Sleeping accommodations are provided for eight people/unit.

- Occupant amenities include:
  - Bunk beds and storage lockers for personal gear.
  - Individually-switched overhead fluorescent lights that enable one end to be illuminated while the other is darkened.
  - Convenience outlets located at each bunk for personal electronics.



### Latrine Shelters

Toilets collect wastes in bio-degradable containers:

- No water or chemicals are required:
  - Is environmentally safe and simple
  - Partitions/curtains provide privacy
  - Stainless steel sinks and high-polish mirrors serve wash-up
  - Overhead fluorescent lights and exhaust fans are standard
  - Environmental Control Units (ECUs) are available as an option



### Laundry Shelters

Special shelters are available to meet laundry needs in remote locations:

- Basic shelter accommodations include:
  - Two heavy-duty commercial washers and two heavy-duty commercial dryers that can be upgraded to industrial grade.
  - A high-capacity water tank and heater.
  - Overhead fluorescent lighting and laundry folding/sorting tables.



### Shower Shelters

Three shower columns are provided in each unit.

- Water is stored in passive tanks:
  - A hot water heater, pump and mixing valve enable preset temperatures.
  - A stainless steel interior resists corrosion and offers easy cleanup.
  - Overhead fluorescent lights and exhaust fans are standard, and ECUs are optional.



### ISO Accommodation Shelters

### Fixed- Volume Types

MODULAR UNITS

CARGO TRANSPORT



The first Capsule Hotel (the Capsule Inn) was opened for use in the Umeda District of Osaka, Japan in 1979.

Essentially these hotels are conventional commercial structures which contain from about 50 to more than 700 small sleeping units that are rented on a daily basis:

- Low prices offer a strong appeal to users, ranging from \$24-\$34/night.
- The capsules offer just enough interior space to sleep, read and watch TV, ranging in size from about 6ft-6.5ft in length.
- Units are stacked two high, and high-density occupancy can present noise levels that make sleeping difficult for many.

### Kisho Kirokawa



Capsule Hotel, Osaka, Japan

Fixed- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**

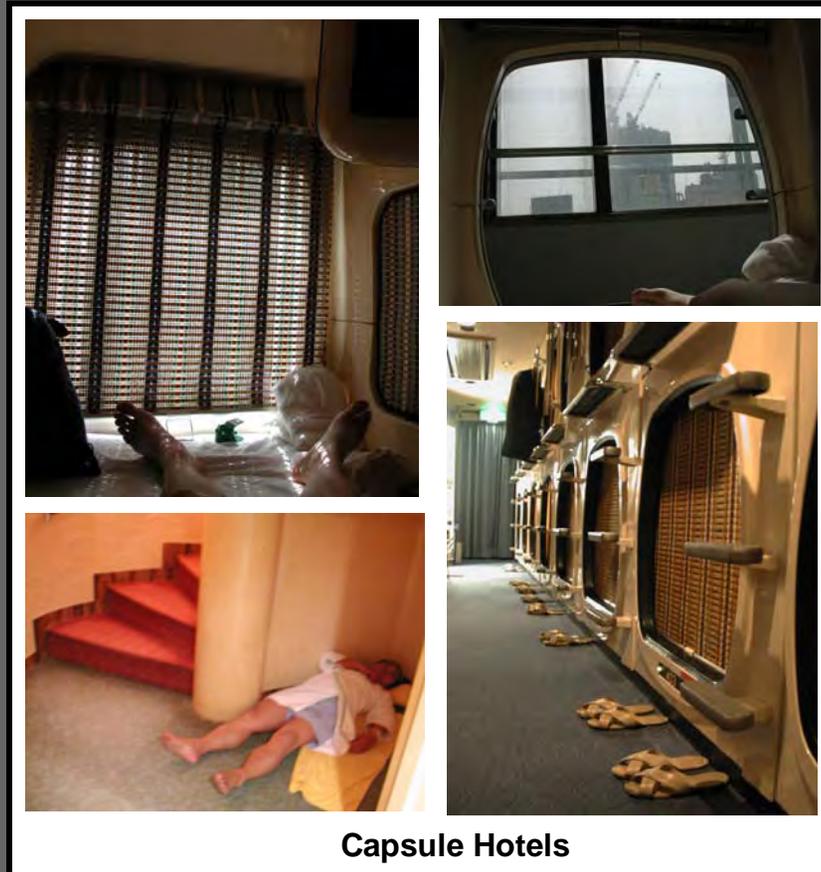


There are several Capsule Hotels in Tokyo which are typically located near train stations to absorb people (usually men) who miss their train home or aren't sober enough to stumble home.

▪ Some, such as one in Omori-Mizuho, provide communal amenities such as roman-styled baths:

- The hotel in Shinbashi features a generous lobby and American porn channels that are popular with users.
- Baggage can be checked at the lobby counter, and clothes can be changed in a locker room.
- Drunken behavior is a common problem, and some renters have been known to pass out before they succeed in accessing their units.

### Kisho Kirokawa



**Capsule Hotels**

Fixed- Volume Types

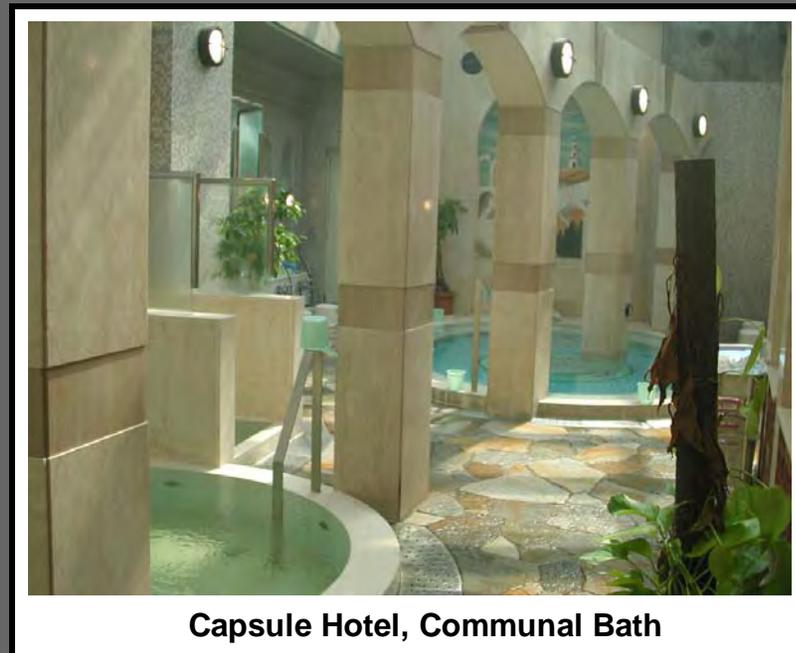
**MODULAR UNITS**

**CARGO TRANSPORT**



**Interiors and Surroundings**

**Kisho Kirokawa**



**Capsule Hotel, Communal Bath**

**Fixed- Volume Types**

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**MODULAR UNITS**

**CARGO TRANSPORT**

Kisho Kurokawa



Fixed- Volume Types

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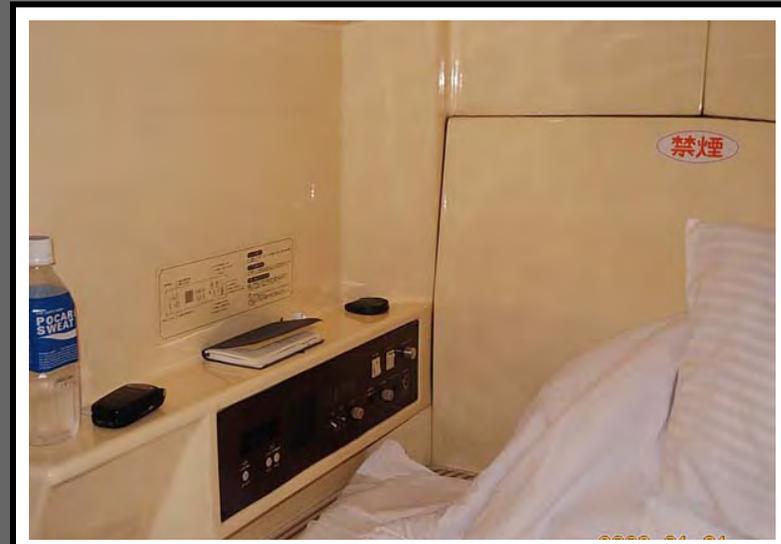
**MODULAR UNITS**

**CARGO TRANSPORT**

Kisho Kirokawa



**Capsule Sleeping Units**



**Capsule Unit Interior**

Fixed- Volume Types

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**MODULAR UNITS**

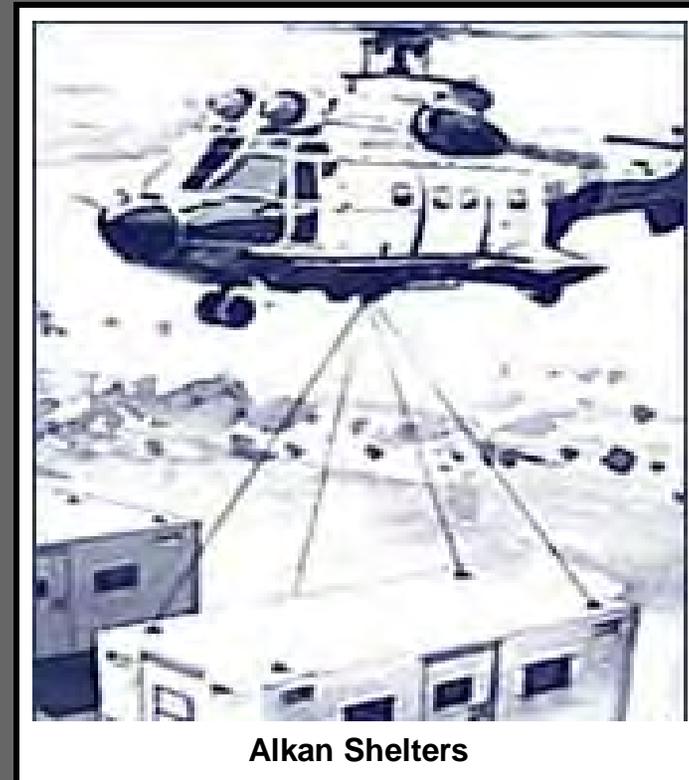
**CARGO TRANSPORT**



## ALKAN SHELTERS

Alkan Shelter of Fairbanks, Alaska produces a variety of modular lightweight carbon composite units for extreme settings.

- The company's ISO shelters provide environmentally controlled work/ living space for such applications as field hospitals, maintenance facilities, tactical operation centers, command posts, field kitchens, and medical and research labs:
  - ISO shelters are wired for 3-phase electrical distribution with integrated fluorescent lights, 120 VAC, 20 amp electrical outlets, an external area light and an external environment control unit interface.
  - The shelters are also available in one and two-side expandable versions and can be stacked up 9-high for shipping.



**Alkan Shelters**

**Fixed- Volume Types**

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**MODULAR UNITS**

**CARGO TRANSPORT**

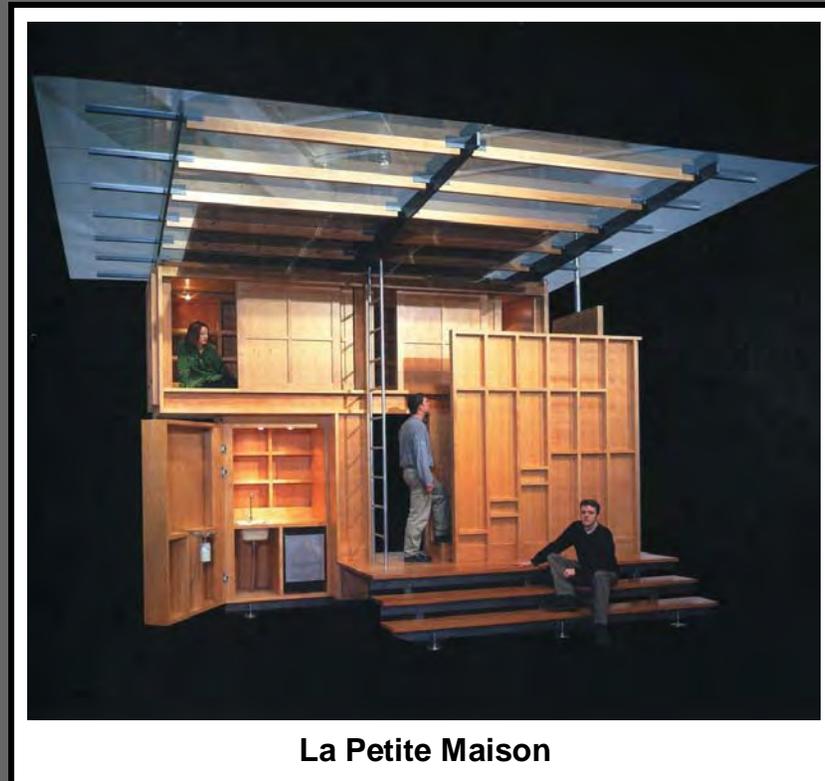


Designed much like a large piece of furniture, this tiny habitat developed in Canada (2001) provides a sleeping loft, kitchenette with deep storage space and a shower.

- The dwelling is constructed primarily from renewable materials:
  - The structure is made of hemlock spruce with steel reinforcement where required.
  - A large 4.3m x 6m roof fabricated from glass and steel reaches out beyond the dwelling to provide shade and shelter.
  - There are no physical barriers to define interior and exterior spaces since the building is essentially an “outdoor room”.
  - Photovoltaic cells installed on the roof provide electricity that is stored in batteries to power lighting, a high-efficiency refrigerator and a toilet fan.

Patkau Architects

MOVE HOUSE



La Petite Maison

Fixed- Volume Types

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**MODULAR UNITS****CARGO TRANSPORT**

**MOVE HOUSE**  
Patkau Architects



**La Petite Maison**

**Fixed- Volume Types**

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**MODULAR UNITS**

**CARGO TRANSPORT**



Werner Aisslinger's Loftcube (Germany) is a portable penthouse designed to be placed on city-center roof tops to expand the owner's space.

- The unit offers only 36 square meters of space but provides the comfort of a luxury hotel room:
  - The interior features a kitchen, bathroom and a sleeping area.
  - A dual-purpose faucet integrated into a slender dividing wall between the bathroom and living area can be levered to water plants or serve as a shower head.
  - A similar faucet in the panel between the kitchen and bathroom serves both the kitchen sink and bathroom wash basin.
  - Outer walls are made up of individual panels available in opaque, translucent or transparent material as desired.

Werner Aisslinger

MOVE HOUSE



The Loftcube

Fixed- Volume Types

MODULAR UNITS

CARGO TRANSPORT

Werner Aisslinger

MOVE HOUSE



The Loftcube

Fixed- Volume Types

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MODULAR UNITS

CARGO TRANSPORT

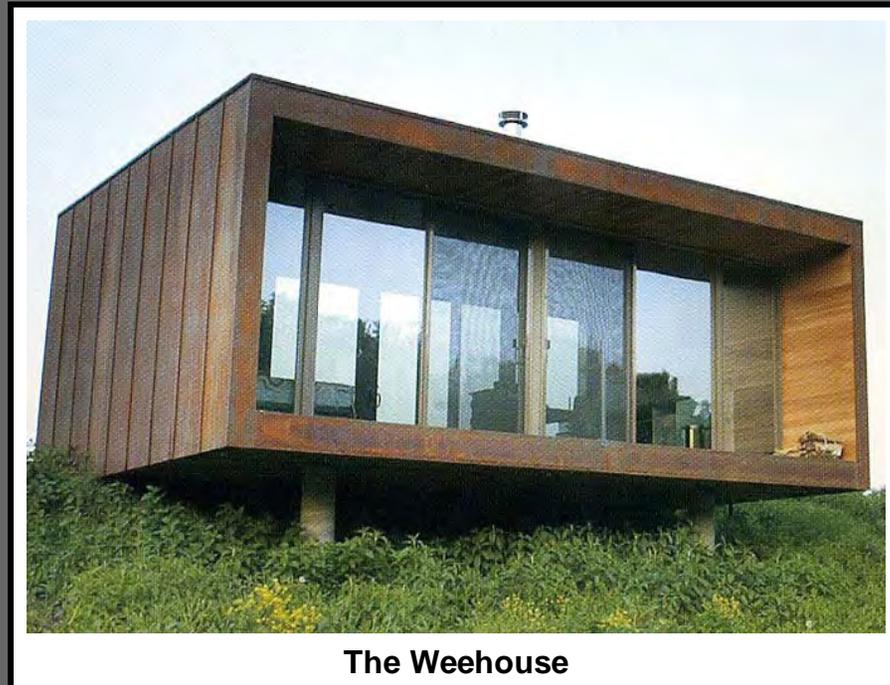


The Weehouse was designed as a small dwelling for a person who doesn't require or desire a large space and/ or is on a very limited budget.

- The structure is delivered to the site by a truck and is craned into place:
  - The unit is constructed of a wood and steel frame with an oxidized metal exterior.
  - Full-height, full-width sliding glass doors provide access, illumination and views.
  - Interior wall surfaces are made of fir, and a wood stove provides heating.
  - The prototype house was constructed for only \$45,000.

Alchemy Architecture

PREFAB MODERN



The Weehouse

Fixed- Volume Types

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**MODULAR UNITS****CARGO TRANSPORT**

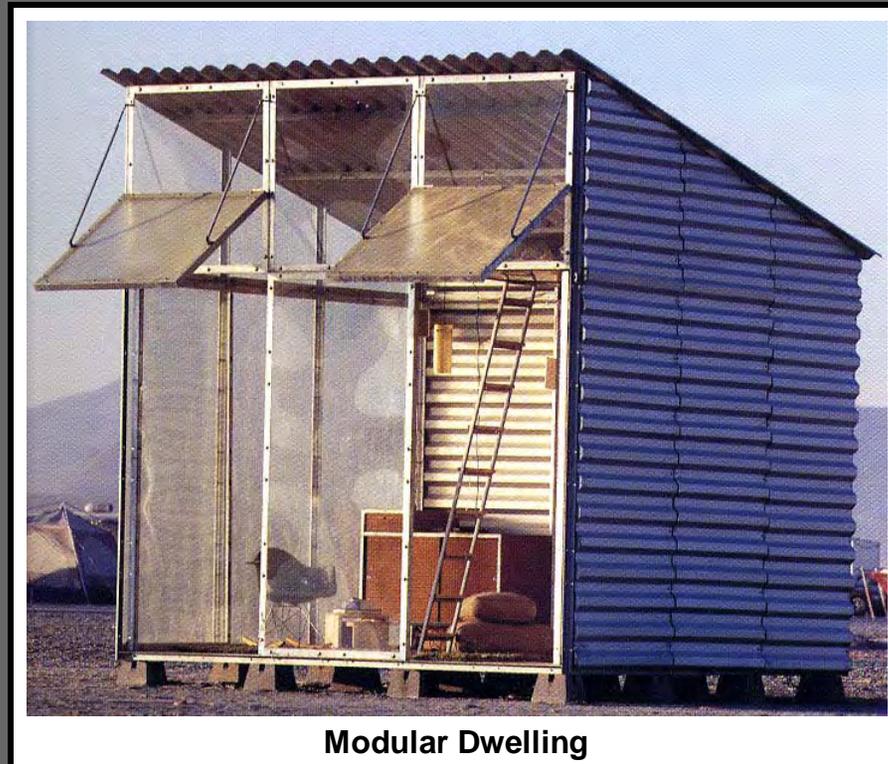


Edgar Blazona, a furniture designer and welder has created modular homes that usually consist of one room which are portable or easy to assemble on site.

- Of the two portable units that he has developed, one was built as a guest room, and the other as a dwelling unit at a “Burning Man” festival celebration held in the Nevada desert in 2003:
  - One model features awnings that extend out from a window wall to provide air circulation.
  - Construction typically uses standard industrial materials to minimize cost.

Edgar Blazona

PREFAB MODERN



Modular Dwelling

Fixed- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**



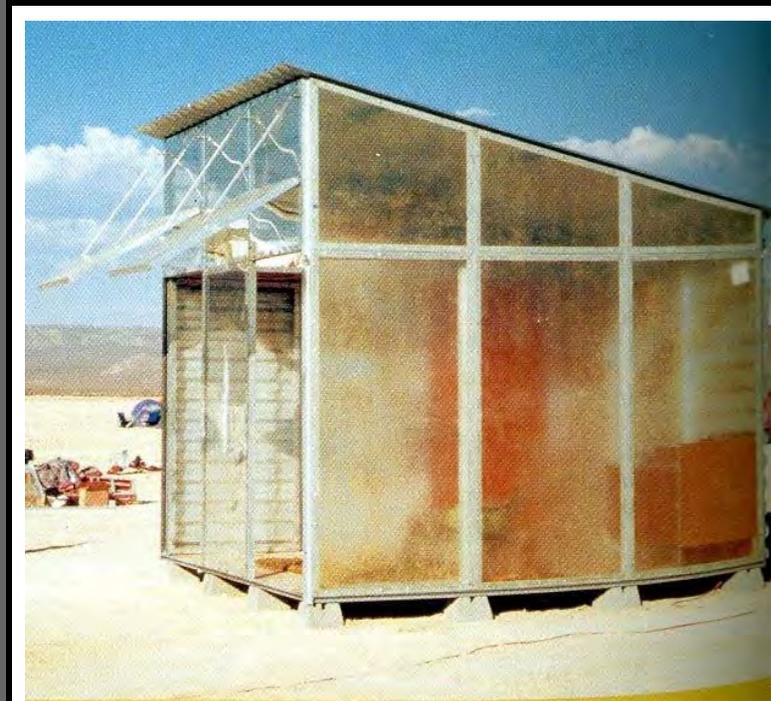
Blazona's MD144 dwelling was constructed with a combination of materials including wood, galvanized steel, fiberglass, Lucite and Plexiglas panels, and corrugated metal. The 15ft x 15ft structure can be packed as flat components for delivery to the site.

Edgar Blazona

MOVE HOUSE



Site Preparation for Installation



MD 144 Modular Dwelling

Fixed- Volume Types

MODULAR UNITS

CARGO TRANSPORT



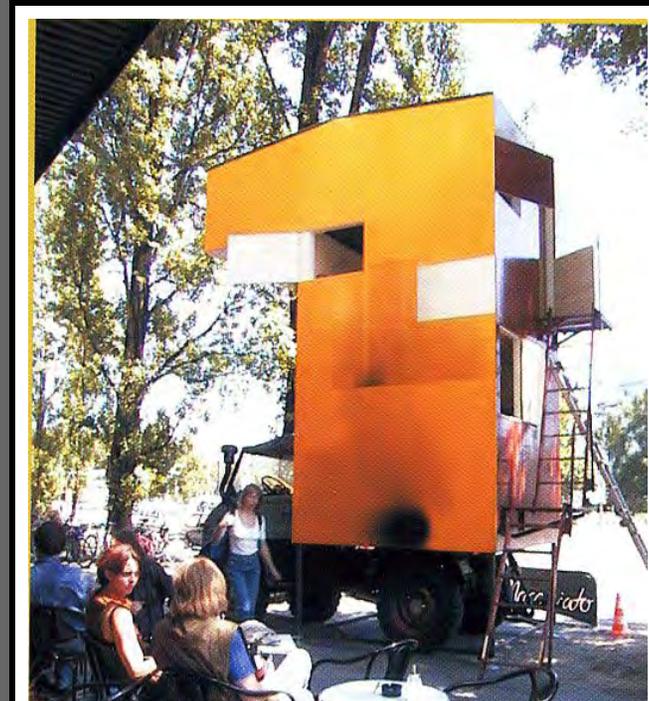
Otto Steidle's Nomad's Tower was developed as a combination home, work place and exhibit. The metal frame structure is covered by a wood skin. Shutters open to reveal a sleeping cabin and a number of television monitors that display images to outside viewers.



**Installation at 2000 Venice Biennale**

Otto Steidle

**MOVE HOUSE**



**Nomad's Tower, Germany**

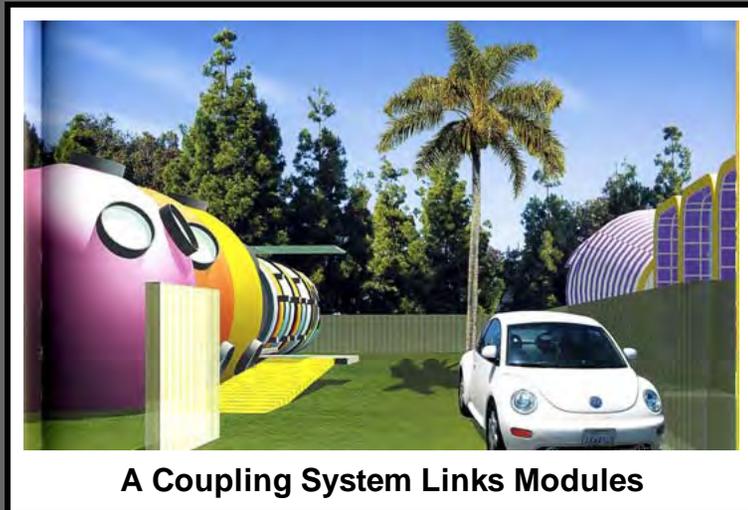
Fixed- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**



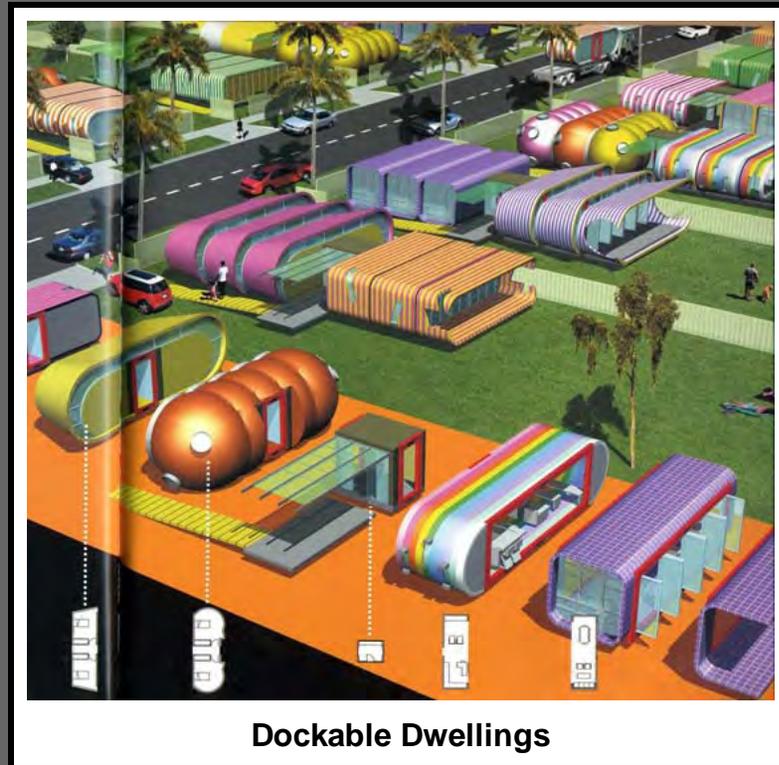
Matias Creimer's Dockable Dwelling concept (Argentina) won the 2003 Home House Project Award from the Southeastern Center for Contemporary Art in California. Seven interconnecting modules would include a terrace, a kitchen, a living room and dining area, a hallway and porch, a two-bedroom unit, a master bedroom/bathroom unit, and a bedroom/laundry/bathroom unit.



**A Coupling System Links Modules**

Matias Creimer

MOVE HOUSE



**Dockable Dwellings**

Fixed- Volume Types

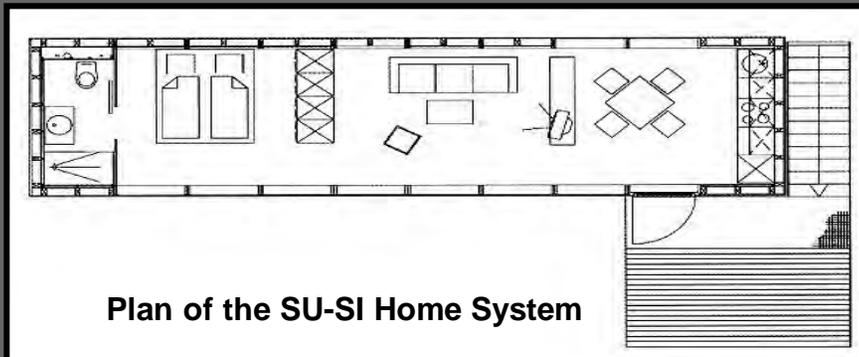
**MODULAR UNITS**

**CARGO TRANSPORT**



KFN's "mobile home" system called SU-SI is a structure that can be transported by truck and installed on a site within a period of five hours.

- Several options are available:
  - The structures can be placed on stilts to provide room for a car underneath.
  - Units are available in different sizes ranging from 30-45 feet in length and 9-10.5 feet in width.
  - Exterior and interior materials can be customized according to customer specifications.
  - Typical construction costs are about \$50,000, and production can be completed in five weeks.



**PREFAB  
KFN Systems**

C-26



**SU-SI Home System**

**Fixed- Volume Types**

**MODULAR UNITS**

**CARGO TRANSPORT**



**PREFAB  
KFN Systems**



**KFN's SU-SI Home System**

**Fixed- Volume Types**

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**MODULAR UNITS**

**CARGO TRANSPORT**

**FEATHERWEIGHTS**  
**KFN Systems**



**KFN's SU-SI Home System**

**Fixed- Volume Types**

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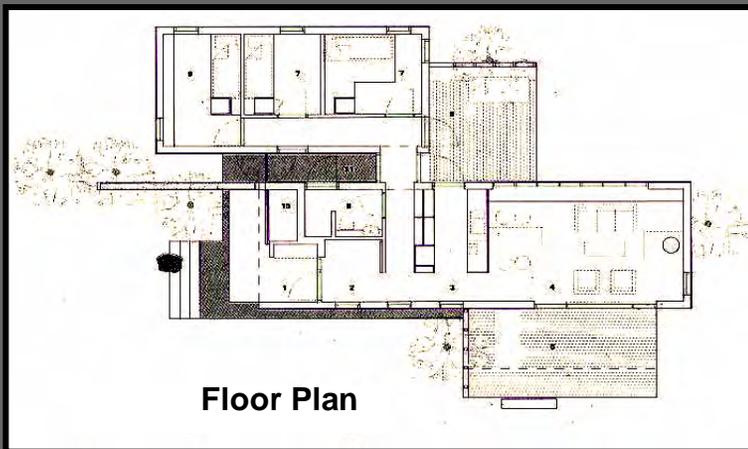
**MODULAR UNITS**

**CARGO TRANSPORT**



Olafur Mathiesan of Glama Kim Arkitektar designed a prefabricated modular home comprised of two wood frame structures clad on the outside with corrugated steel.

- A 12ft wide x 40ft long main house contains an open kitchen/dining space, entryway, bathroom and exterior storage.
- A smaller 12ft wide x 24ft long structure contains the sleeping areas.



Floor Plan

PREFAB  
Glama Kim Arkitektar

C-29



Summer House in Halsaveit, Iceland

Fixed- Volume Types

MODULAR UNITS

CARGO TRANSPORT



Fixed- Volume Types

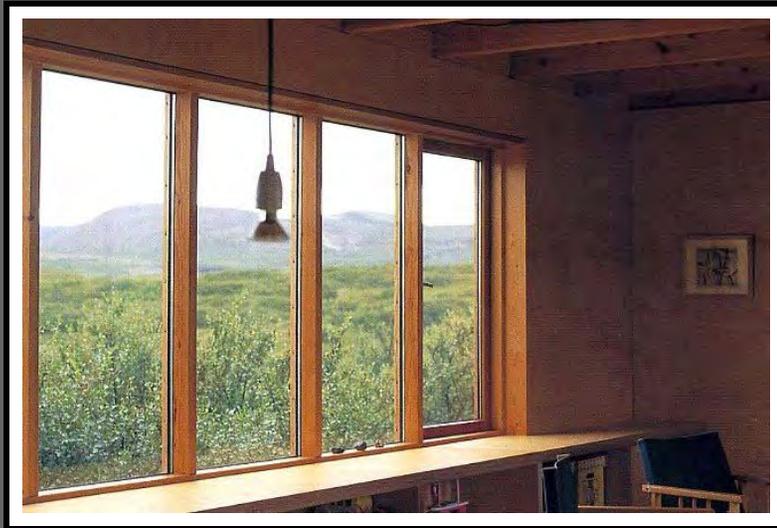
**MODULAR UNITS**

**CARGO TRANSPORT**

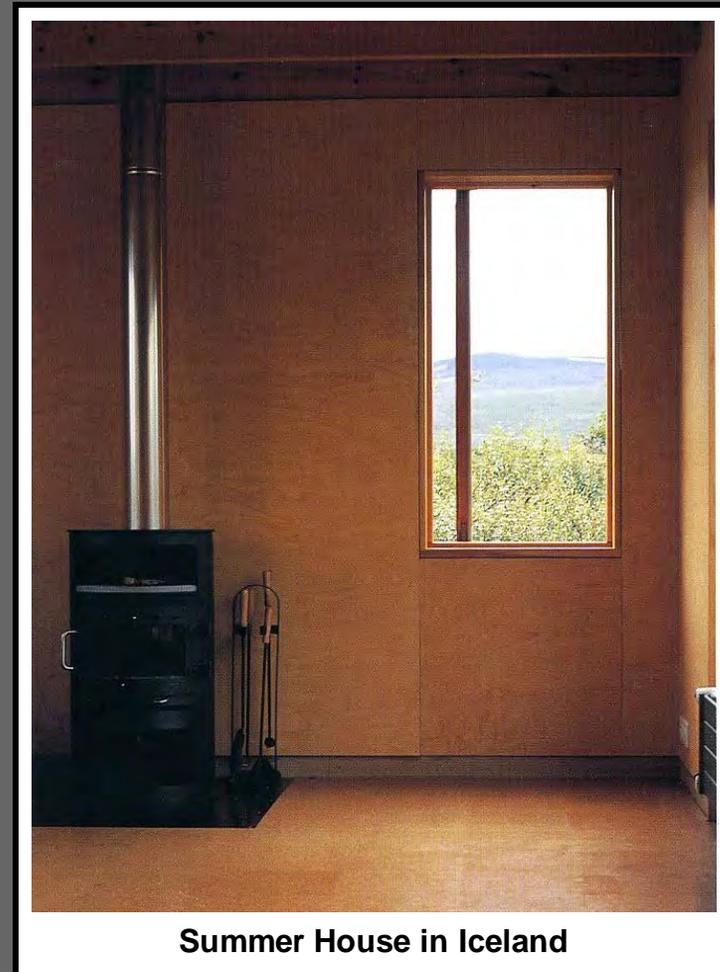


PREFAB  
Glama Kim Arkitektar

C-31



Designed for a family of five, the open plan of the main house affords panoramic views of a distant mountain and glacier. The home is heated by geothermal water from wells on the property.



**Summer House in Iceland**

Fixed- Volume Types

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**MODULAR UNITS**

**CARGO TRANSPORT**



White on White Design has created a \$30,000 house assembled from interchangeable 6ft x 12ft x 8ft modules.

- The modules can be put together in different combinations and configurations to adapt to varying design needs:
  - Their modular house prototype was formed from 4 modules, providing a total of 576ft<sup>2</sup>.
  - The one bedroom home features a built-in bed, a glass skylight, a well-applianced kitchen with 6 chairs, and various other furnishings.

### White on White Design

### PREFAB MODERN



White on White Design

Fixed- Volume Types

**MODULAR UNITS**

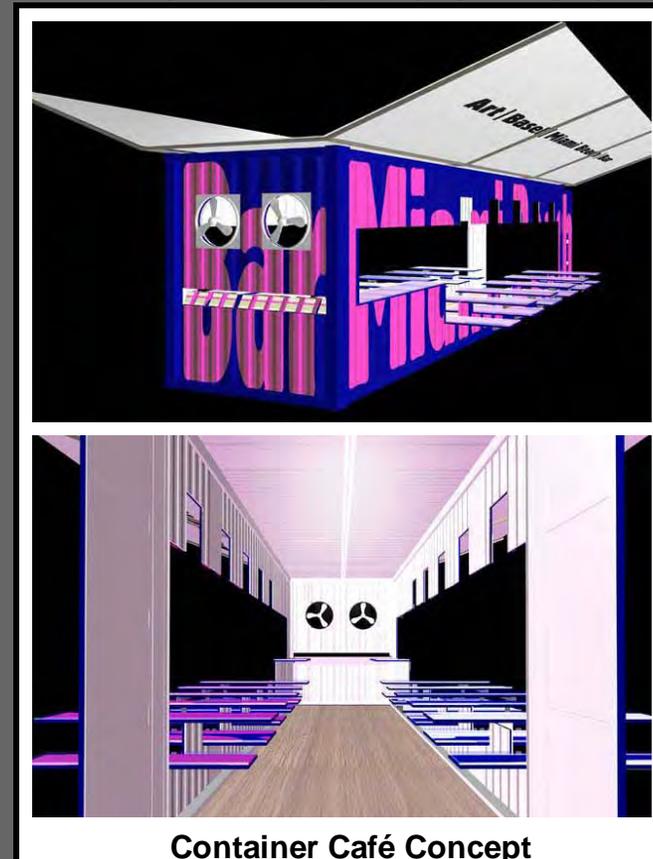
**CARGO TRANSPORT**



## LOT-EK ARCHITECTURAL STUDIO

The LOT-EK Architectural Studio has proposed to create a transportable bar/café from a single 40ft long, 8ft wide shipping container.

- The container's corrugated metal skin would be manipulated to serve various functions:
  - Side panels can be hinged upwards to provide canopies over dining areas.
  - Cutouts in the long side of the container would be folded to a horizontal position to act as tables and benches.
  - Two long counters at one of the container would be folded opposite to each other to create an inside serving area.



Fixed- Volume Types

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**MODULAR UNITS****CARGO TRANSPORT**



Modular design of the Murray Grove Apartments was guided by a need to create high quality affordable housing that could be implemented in a short period of time.

- The 32 unit single-bedroom flats were each comprised of two 10ft x 24 ft steel-framed boxes stacked into a 5 storey structure:
  - The entire building was erected in only 10 days.
  - Exteriors were clad with clip-on terracotta rain screens, and the roof was covered with steel panels.
  - An elevator and stair tower were fabricated separately, with apartment access via external balconies.

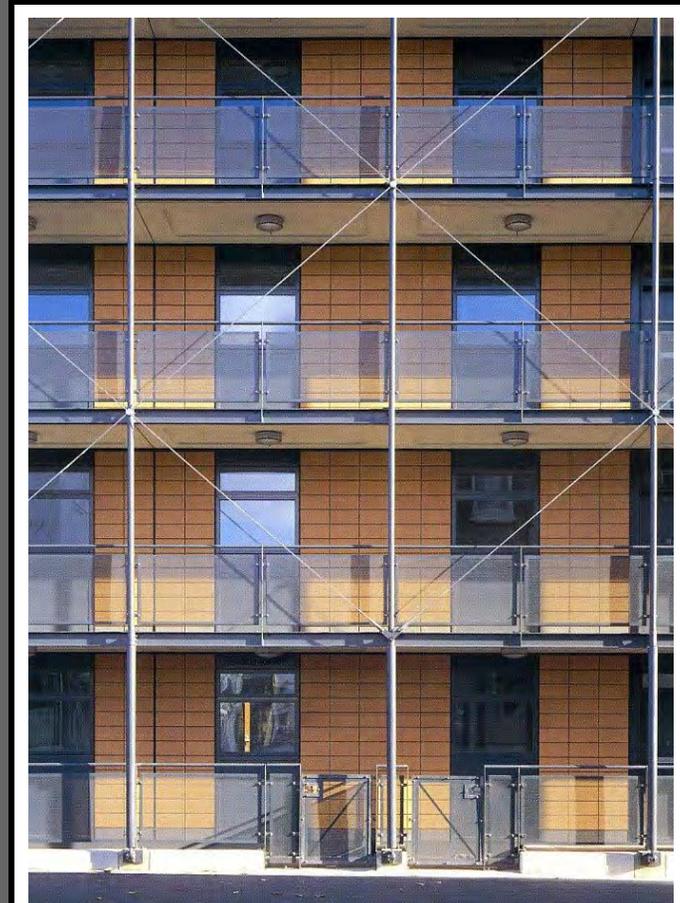


**Flats Range From 600-800 Square Feet**

## PREFAB

Cartwright Pickard Architects

C-34



**Murray Grove Apartments, London**

Fixed- Volume Types

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**MODULAR UNITS**

**CARGO TRANSPORT**



**PREFAB**  
**Cartwright Pickard Architects**



**Murray Grove Apartments Fabrication and Assembly**

**Fixed- Volume Types**

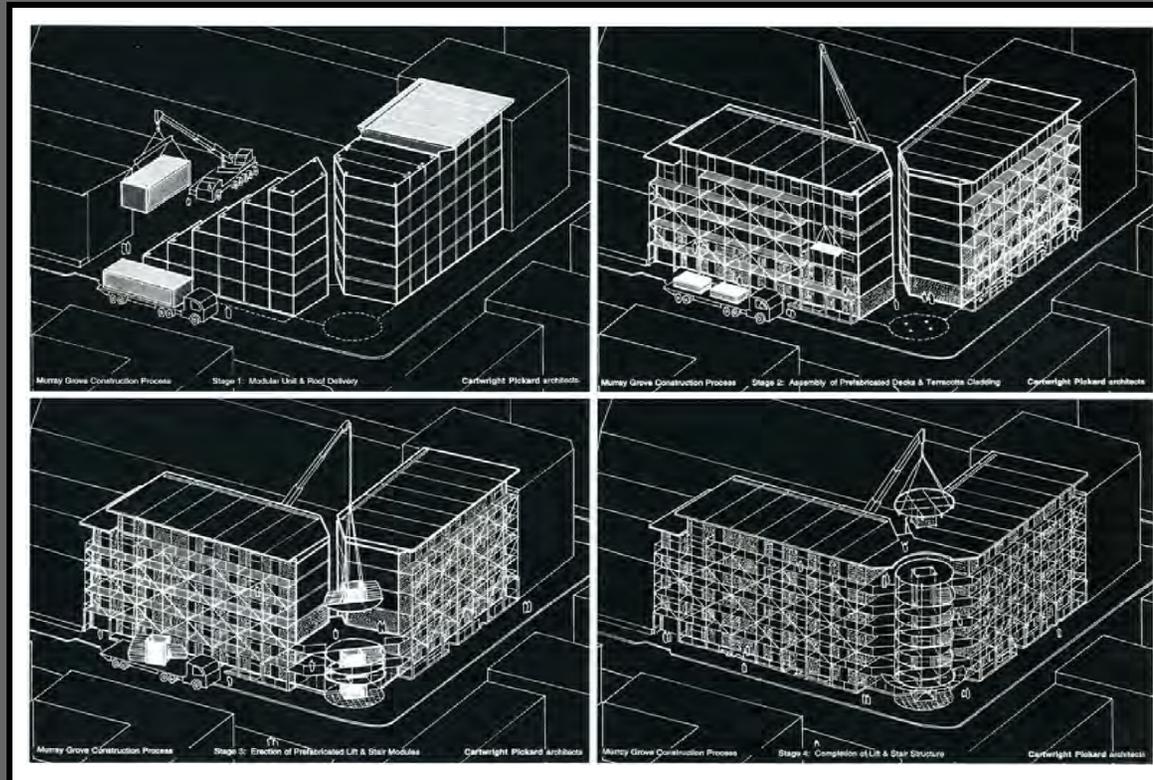
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**MODULAR UNITS**

**CARGO TRANSPORT**



PREFAB  
Cartwright Pickard Architects

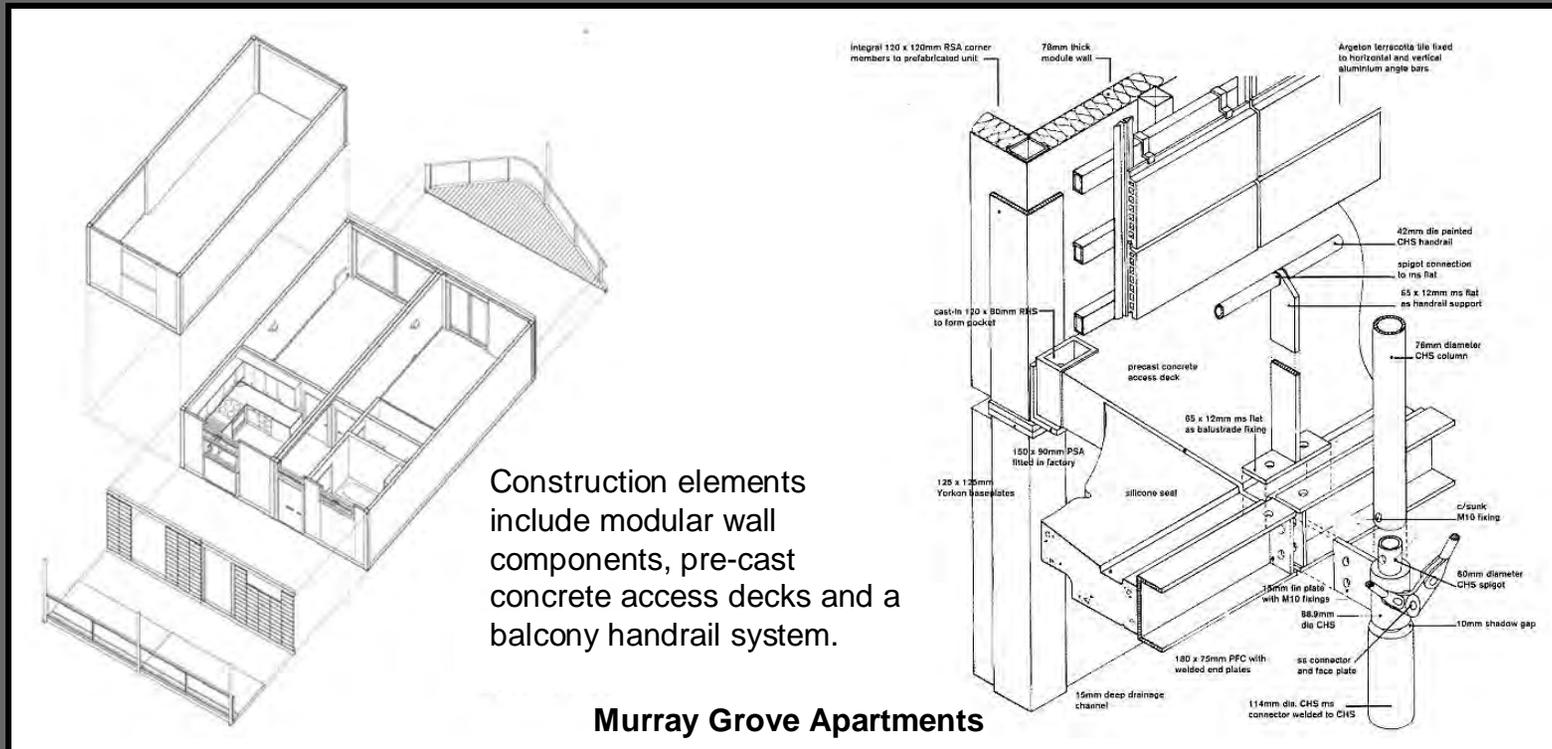


Fixed- Volume Types

MODULAR UNITS

CARGO TRANSPORT

**PREFAB**  
**Cartwright Pickard Architects**



**Fixed- Volume Types**

**MODULAR UNITS**

**CARGO TRANSPORT**

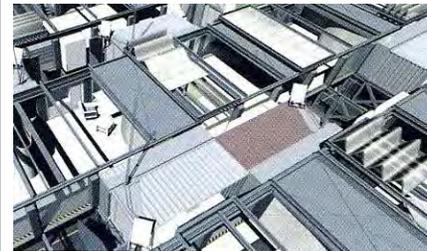


Doug Jackson/Large has proposed a community of physically networked housing units based upon 20ft 150 shipping containers that can accept “plug-in” fixture modules to accommodate storage and hygiene needs.

- Transverse sliding partitions within units would allow occupants to change spaces as desired during different day/night activity periods:
  - Flexible silicon rubber partitions suspended from a two-degree-of-freedom carriage system with translucent perimeter screens would enable enclosed spaces to be created either on interior or exterior areas to form single or joined units.
  - When a flexible partition is folded back on itself against a deployed perimeter screen, an outdoor storage space is created.

## MOBILE Doug Jackson/ Large

C-38



The community was proposed for a 22 acre site in an industrial port area of Oakland, California.

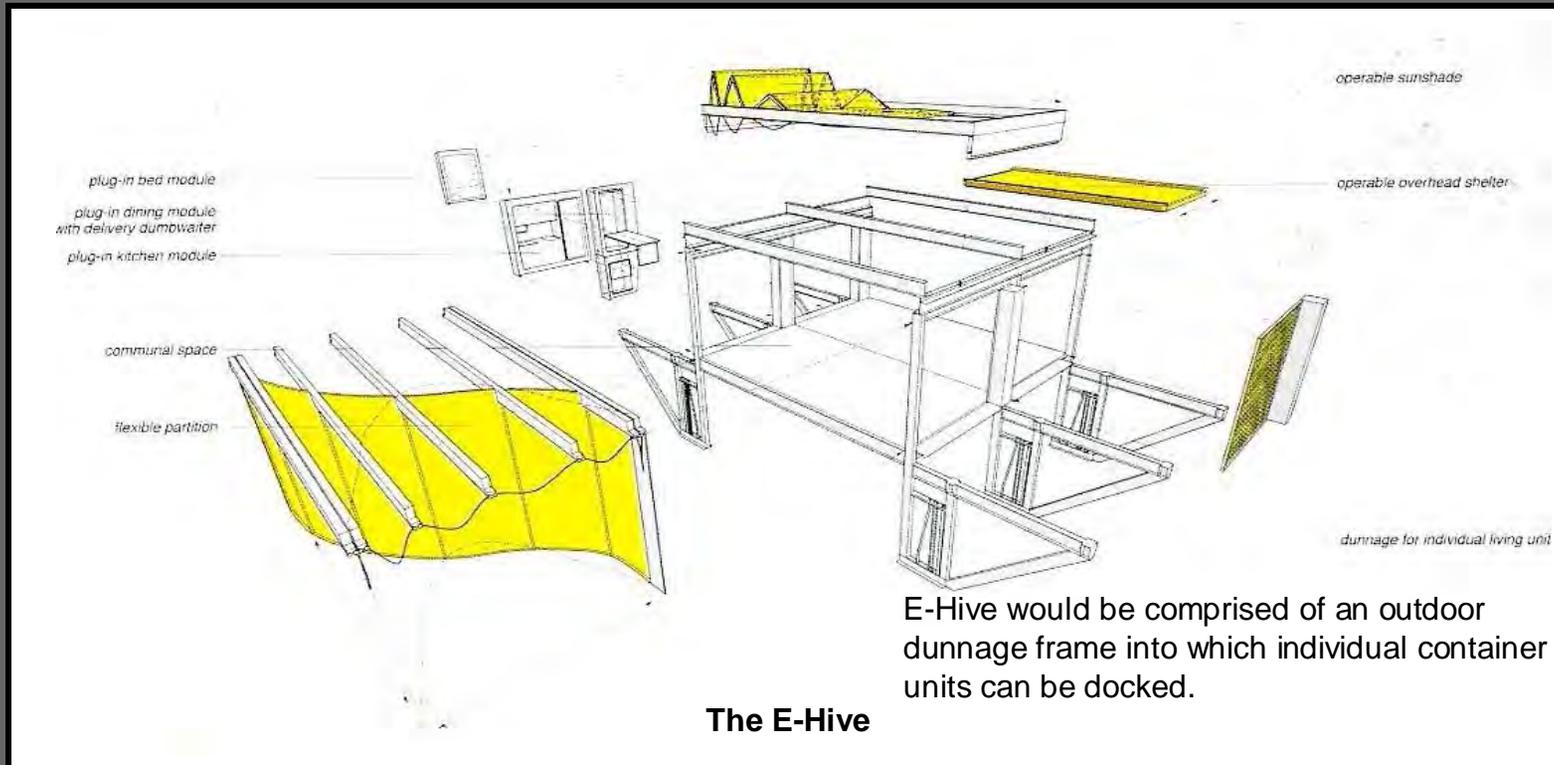
**The E-Hive**

**Fixed- Volume Types**

**MODULAR UNITS**

**CARGO TRANSPORT**

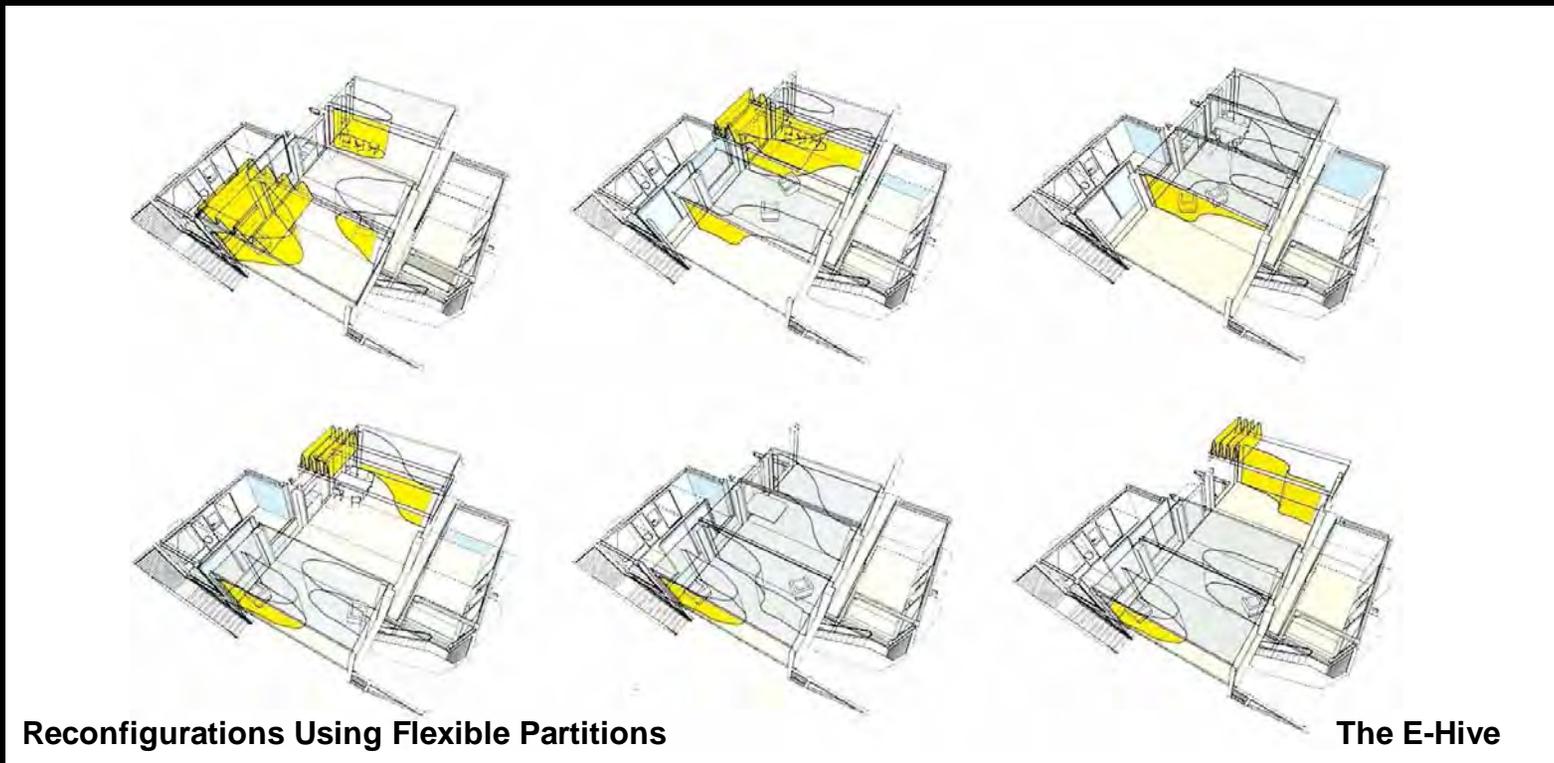
**MOBILE**  
**Doug Jackson/ Large**



Fixed- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**



**Reconfigurations Using Flexible Partitions**

**The E-Hive**

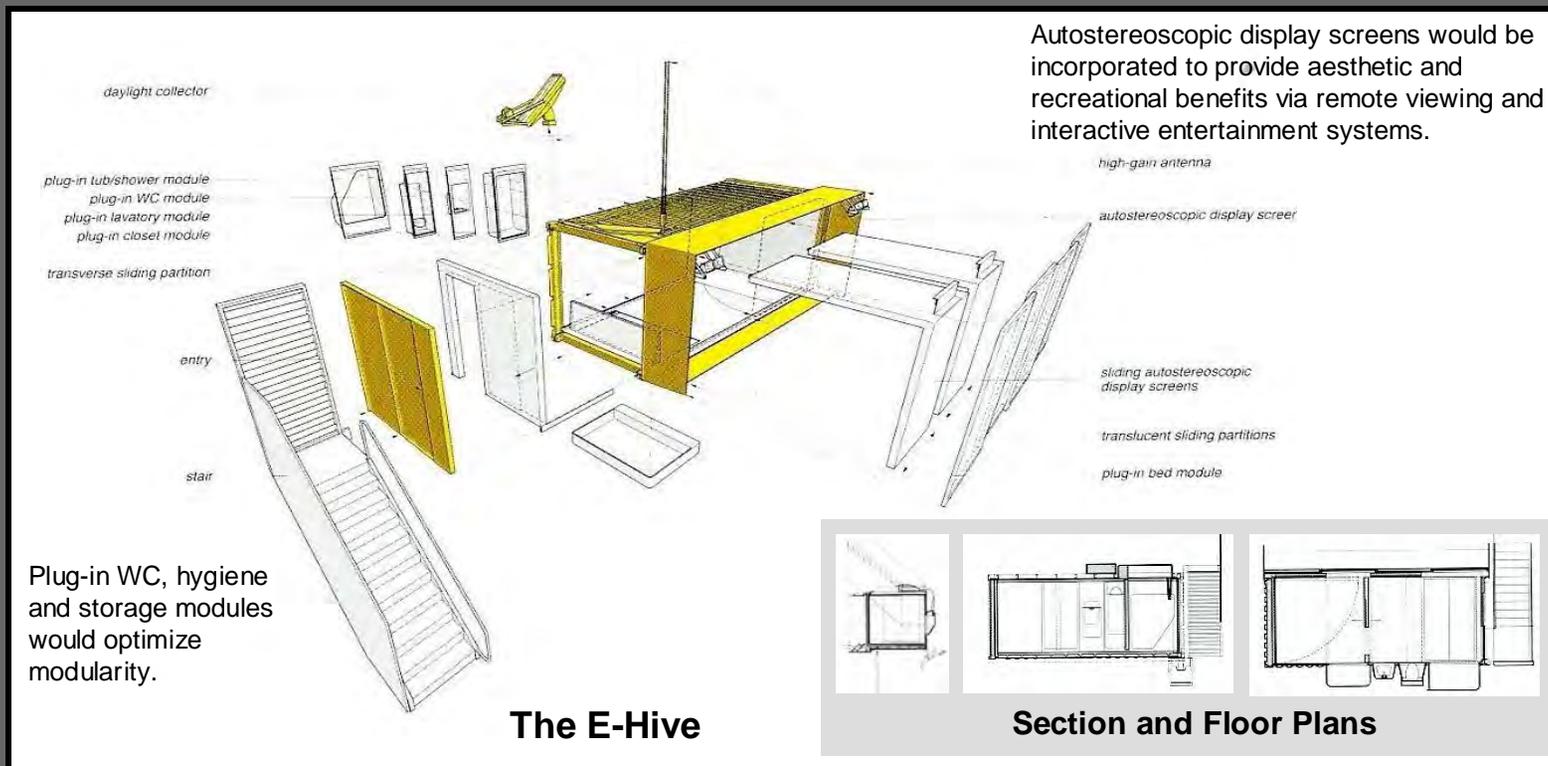
**Fixed- Volume Types**

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**MODULAR UNITS**

**CARGO TRANSPORT**

**MOBILE**  
**Doug Jackson/ Large**



Fixed- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**

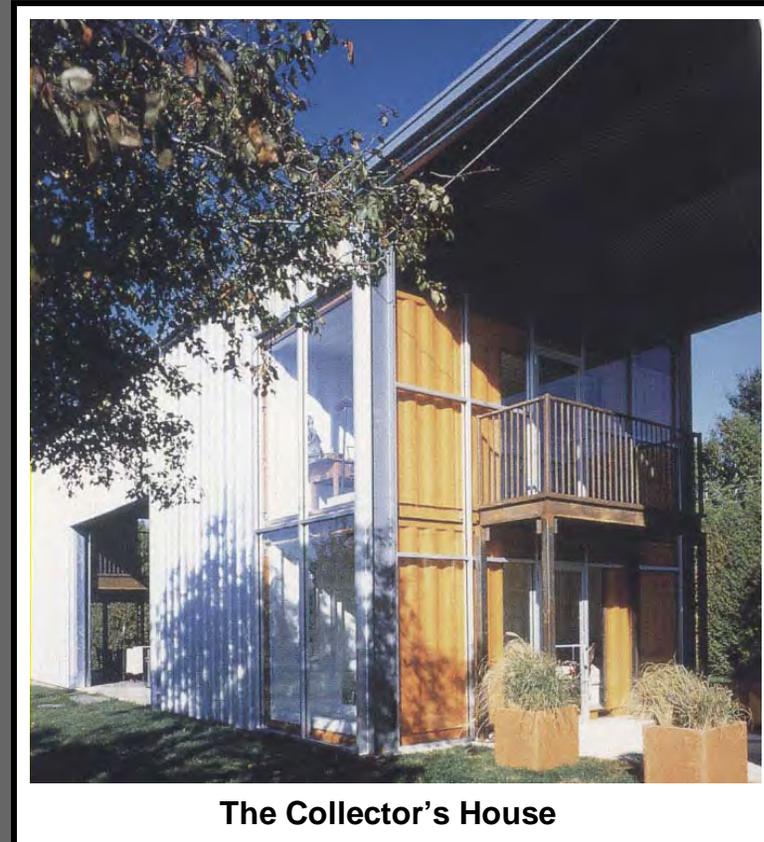


Kalkin &amp; Hadley

PREFAB MODERN

The Collector's House that was displayed at the Shelburne Museum in Shelburne, Vermont was constructed in part from shipping containers painted orange and green for interior walls.

- The design combines elements of steel, glass and garage doors.
  - Adam Kalkin is a designer that works to use elements that are “collected” from existing structural components and modifying them to create inexpensive and innovative architectures.
  - Many of these designs are conceived to be assembled by owners like “balsawood model airplanes” for very low costs.



**The Collector's House**

Fixed- Volume Types

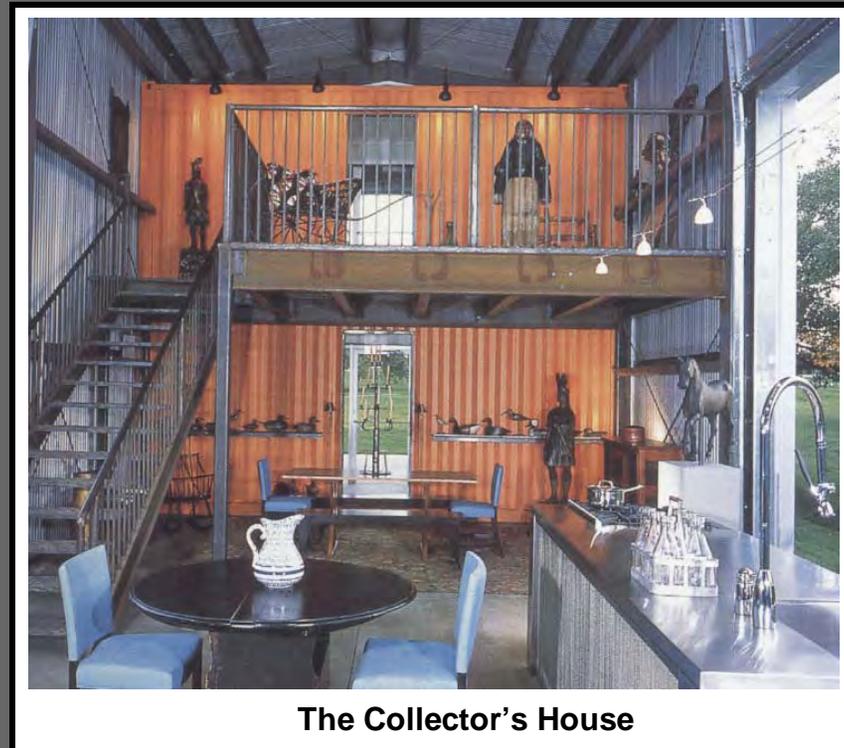
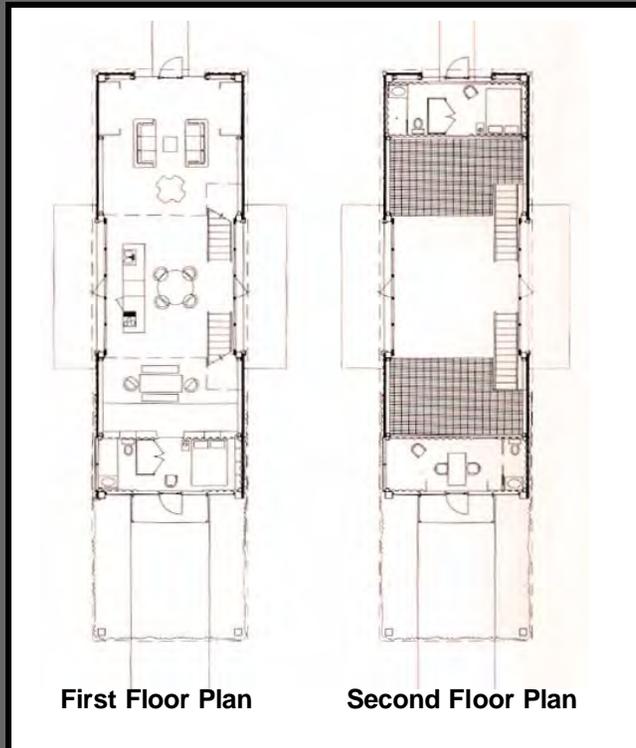
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**MODULAR UNITS**

**CARGO TRANSPORT**

Kalkin & Hadley

PREFAB MODERN



Fixed- Volume Types

MODULAR UNITS

CARGO TRANSPORT

Adam Kalkin's Quick Build House was designed as a second home built from shipping containers:

- Each level of the two-storey structure is comprised of three containers with adjoining side walls removed as desired for connecting doorways and open circulation:
  - Owners can modify the plans and interior elements to suit their particular needs.
  - As with other of Kalkin's schemes, garage doors and other conventional elements can be selected and applied to minimize costs.

Adam Kalkin

PREFAB MODERN



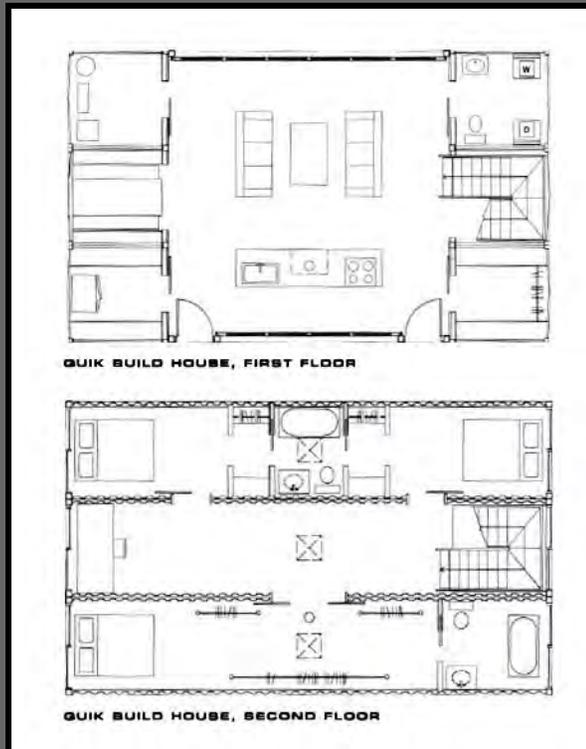
Fixed- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**

Adam Kalkin

PREFAB MODERN



Fixed- Volume Types

MODULAR UNITS

CARGO TRANSPORT



**PREFAB MODERN**

Adam Kalkin

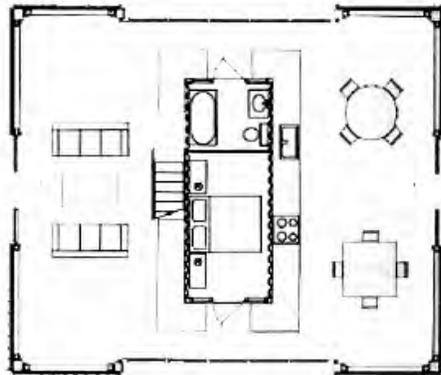
C-46

Adam Kalkin's 99K House design was named for its \$99,000 selling price:

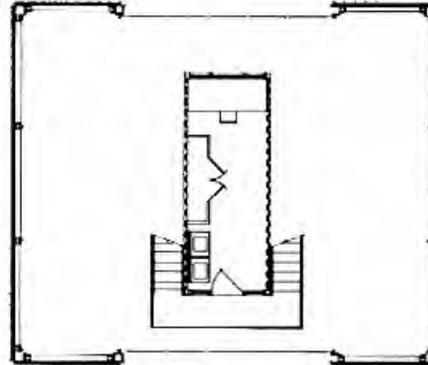
- The three-storey house is constructed of three stacked shipping containers, which can be easily set in place by a forklift.
- Kalkin has proposed other container-derived configurations.



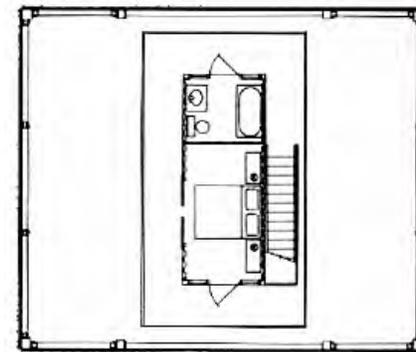
**The 99K House**



**First Floor Plan**



**Second Floor Plan**



**Third Floor Plan**

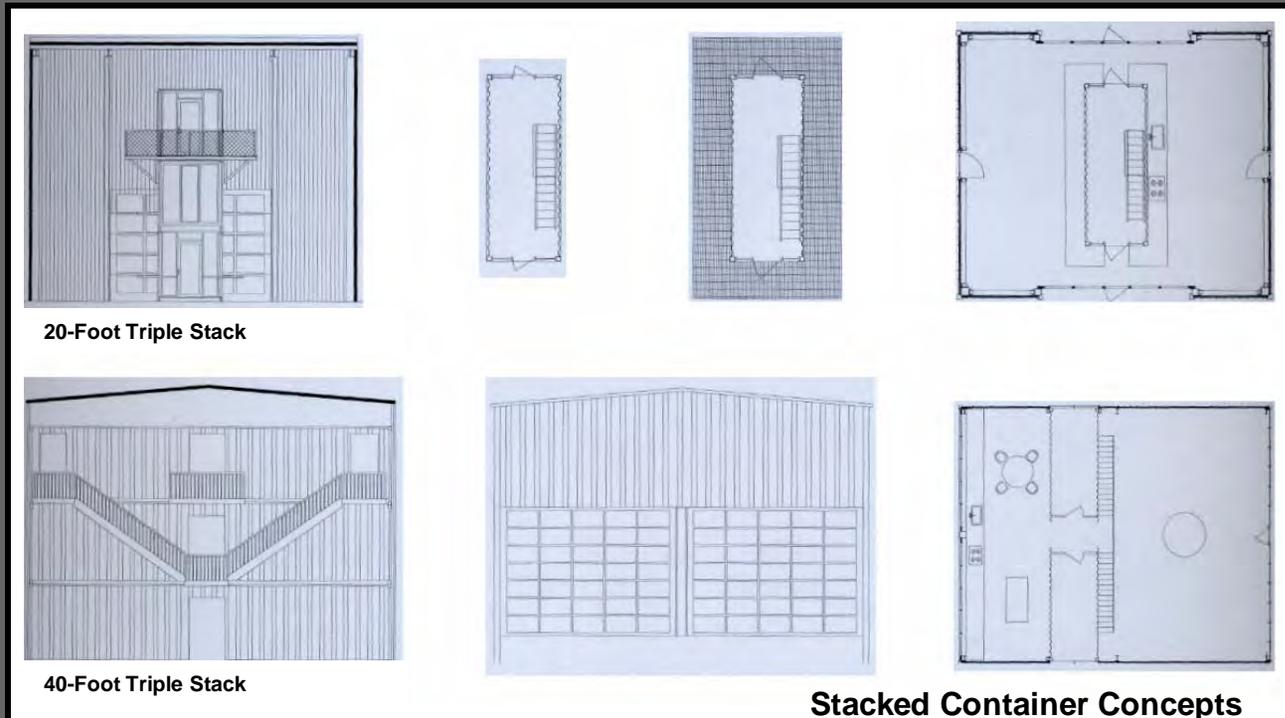
**Fixed- Volume Types**

**MODULAR UNITS**

**CARGO TRANSPORT**

Adam Kalkin

PREFAB MODERN



20-Foot Triple Stack

40-Foot Triple Stack

Stacked Container Concepts

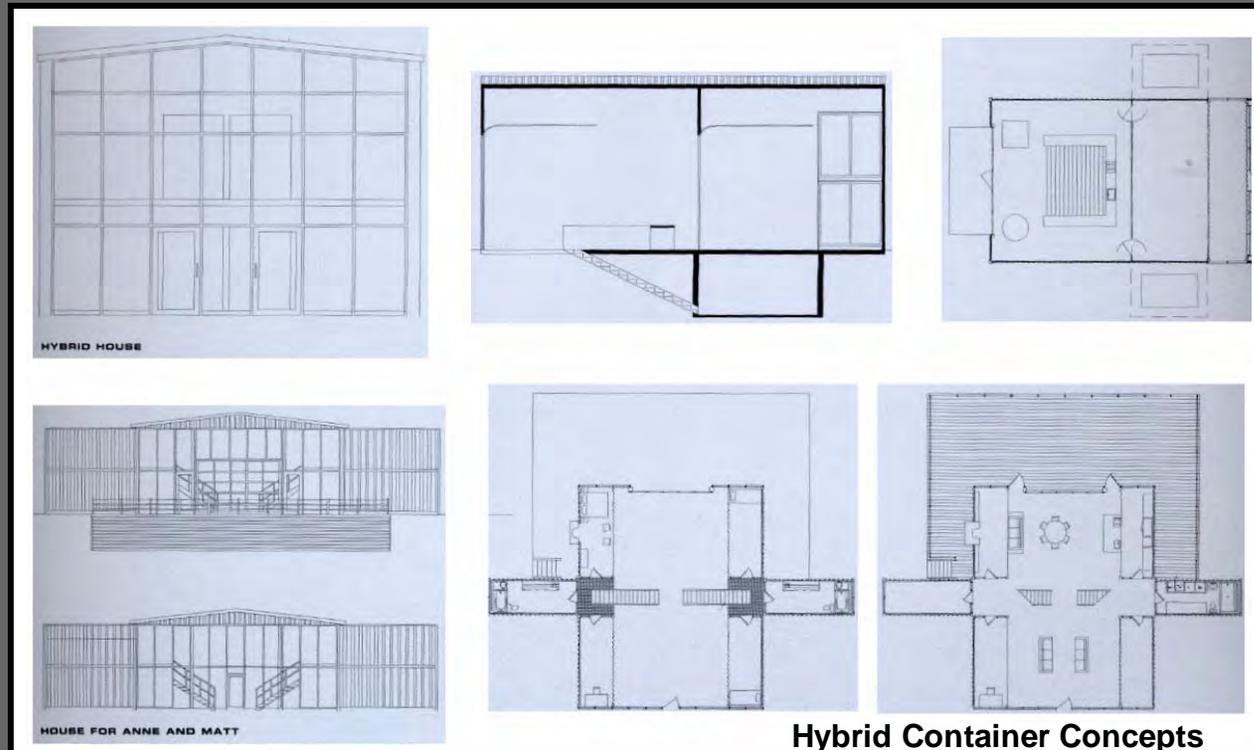
Fixed- Volume Types

MODULAR UNITS

CARGO TRANSPORT

Adam Kalkin

PREFAB MODERN



Hybrid Container Concepts

Fixed- Volume Types

MODULAR UNITS

CARGO TRANSPORT



LOT-EK ARCHITECTURAL STUDIO

The LOT-EK Architectural Studio has proposed a Container Home Kit (CHK) that combines shipping containers to create affordable homes.

- Sections of the corrugated walls of basic 40ft containers can be cut out to create openings between connected containers to provide larger spaces without compromising structural integrity:
  - Containers can be stacked in loft configurations and/or joined side-by-side.
  - Variations include 2-4 bedroom versions using combinations of 4-8 containers.
  - Structures would be positioned on parallel concrete strips and be removable to enable relocation.



**Six Unit Container Home Kit**



**Four Unit Container Home Kit**

Fixed- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**



The Swellhouse combines “smart building” technologies with cost-effective prefabrication methods in a manner that also optimizes owner customization opportunities.

- Components are assembled in a factory as independent modules which are bolted together at the site:
  - Electrical, plumbing and information technologies are concealed within wall cavities as part of the standardized modular system.

## OFFICE OF MOBILE DESIGN (OMD)



**The Swellhouse**

Fixed- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**



- Ecological Sun System (ECOSS) glass panels on the first level are a sandwich of sheet glass with acrylic plastic bars and aluminum louvers that reduce solar heat gain by filtering sunlight from the curtain wall.
- Fiber cement panels on the upper level are held away from the interior wall to produce a rain screen and water barrier while allowing natural air to flow between the wall and cladding.
- A permeable skin of sliding panels form interior courtyards, exterior decks, or a double-height vestibule as desired.

### OFFICE OF MOBILE DESIGN (OMD)



**The Swellhouse**

Fixed- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**



## GICHNER SHELTER SYSTEMS

Gichner's Expandable S-530 A/G shelter is used by the US Department of Defense (DOD) as one of their standard tactical shelters:

- Exterior dimensions in its unexpanded transport configuration are 12'-2" long x 7'-6" wide.
  - Two shelters can be linked together to form a single larger space whereby a roof or floor panel and sidewall of each can extend the volume by an additional third (11'-5" long x 20'-4" wide x 6'-9" high).
  - Six soldiers can accomplish assembly of the expanded volume in 45 minutes.
  - The lightweight construction of aluminum skins over a Nomex core facilitates handling and setup.



**Expandable S-530 A/G Shelter**

**Expandable- Volume Types**

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**MODULAR UNITS**

**CARGO TRANSPORT**



Gichner's Shelter Systems provides a variety of Transportable Expandable Container (TEC) facilities, which can fold out on one or two sides to double or triple the original shipping volume.

- The TEC is available in either steel or aluminum versions:
  - The steel TEC version is a fully CSC certified ISO freight container capable of 9-unit high stacking with nesting expandable sections which can be set up by three trained personnel in about half an hour.
  - The aluminum TEC is a fully certified ISO container that is rated for 4-high stacking.
  - TEC 1:3 two-sided units provide for 306 sq. ft of operational floor space with a partitioned-off technical room providing an additional 22 sq.ft. of floor space for support equipment (e.g. air conditioner, generator and NBC filter systems).
  - During NBC pressurization, a 1:3 TEC can reach 1.4 inches of water pressure within 30 seconds with a filtered air supply of 70ft<sup>3</sup>/minute.

## GICHNER SHELTER SYSTEMS



**Transportable Expandable Container (Utility)**



**Transportable Expandable Container (Shelter)**

## Expandable- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**



LOT-EK ARCHITECTURAL STUDIO

LOT-EK Mobile Dwelling Units (MDUs) are conceived for people who frequently move and desire to transport their home with them complete with all equipment and belongings.

- Container walls telescope out to extend internal volumes following shipment in compacted form:
  - Upon reaching their site destinations, each MDU is lifted by a permanent moving crane device into place within a multi-level steel rack structure (or “harbor”) which contains elevators, stairs and utilities (power, water and sewage).
  - Steel brackets secure MDUs in place where they are connected to utility systems.
  - Outer wall construction is of metal, and interior sub volumes are fabricated from plastic-coated plywood.



LOT-EK Mobile Dwelling Units (MDU's)

Expandable- Volume Types

MODULAR UNITS

CARGO TRANSPORT

**LOT-EK ARCHITECTURAL STUDIO**



**LOT-EK Mobile Dwelling Units (MDU's)**

**Expandable- Volume Types**

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**MODULAR UNITS**

**CARGO TRANSPORT**



The Austrian firm KVN Systems has developed FRED as an expandable room unit that can be extended with electronically operated sliding walls to increase volume following shipping.

- Unit components are provided in different sizes to offer client selection options:
  - The units are fabricated using wood and glass, and are sturdy enough to be stacked.
  - Ten different types of wall facades are available, and room layouts and dimensions are custom designed by the architectural firm.
  - Turnkey construction is available, but clients can also arrange for their own interior and finishing work.
  - Large, well-insulated glass areas offer good views and sunlight.
  - Average construction and implementation costs are about \$100,000 including shipping and foundation work.

## KFN Systems

## PREFAB



**FRED Modular Home System**

**Expandable- Volume Types**

**MODULAR UNITS**

**CARGO TRANSPORT**



C-57

KFN Systems

PREFAB



Installation Requires About 2 Hours



**FRED Modular Home System**

Expandable- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**



The Office of Mobile Design (OMD), an architecture firm located in Venice, California, has proposed lightweight transportable modules as an alternative to conventional home construction and traditional mobile home options.

- OMD's Portable House offers extendable volumes and the ability to be grouped together to create common spaces for courtyards and garden.



Grouped Units Create  
Common Spaces

## OFFICE OF MOBILE DESIGN (OMD)



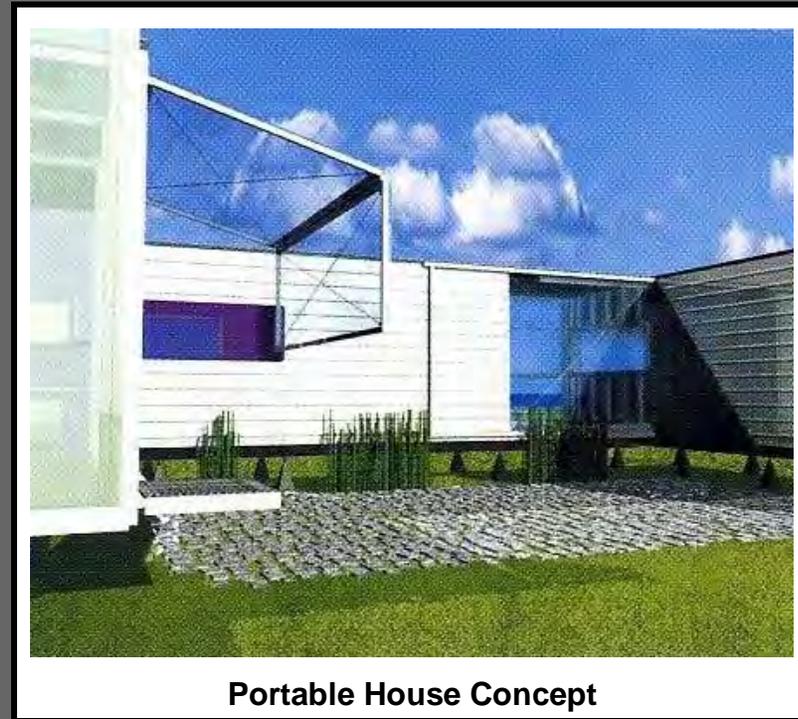
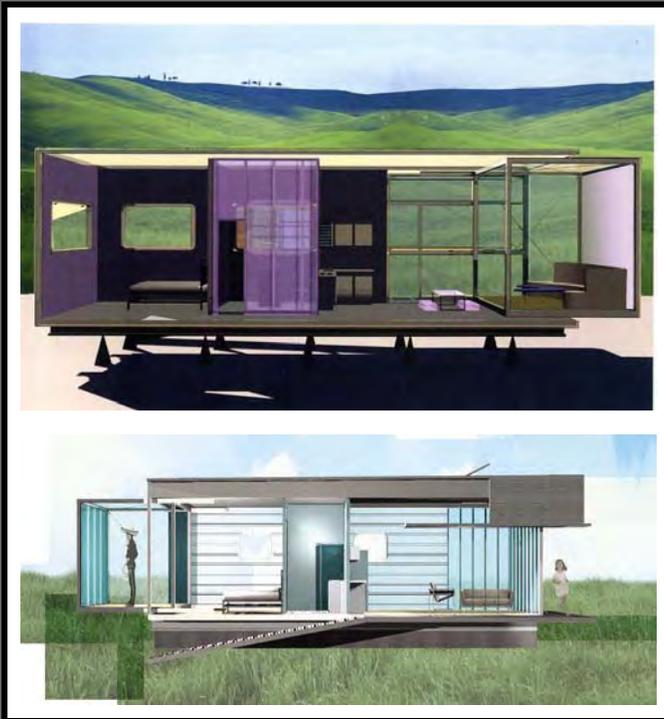
Portable House Concept

Expandable- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**

**OFFICE OF MOBILE DESIGN (OMD)**



**Portable House Concept**

**Expandable- Volume Types**

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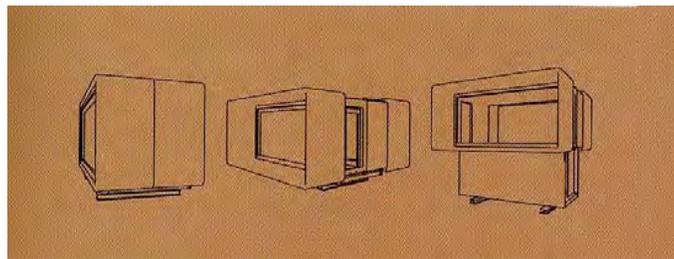
**MODULAR UNITS**

**CARGO TRANSPORT**



Peter Haimerl's Cocobello (Germany) is designed for multiple applications including a dwelling, studio space or exhibit/marketing facility.

- The module consists of three interlocking components that deploy using a pneumatic device to form a two-storey space:
  - The bottom level is designed to accommodate a small bathroom, kitchen and storage space.
  - The upper tier provides an expandable space with large windows at each end.
  - The structure is strong and light, manufactured from steel pipes with plastic panel and carbon-fiber outer cladding.



**Deployment Scheme**

Peter Haimerl

MOVE HOUSE



**Cocobello Multipurpose Facility**

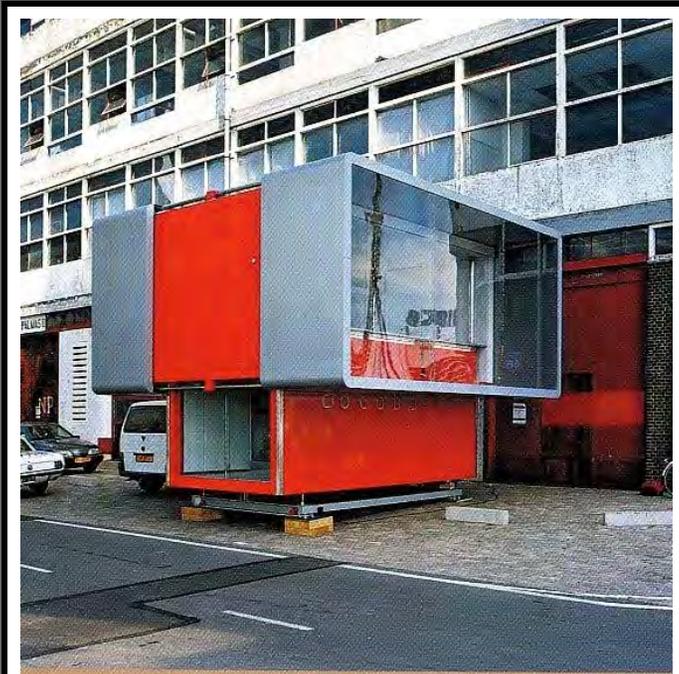
Expandable- Volume Types

**MODULAR UNITS**

**CARGO TRANSPORT**

Peter Haimerl

MOVE HOUSE



A Pneumatic Device Lifts the Upper Tier



Cocobello Multipurpose Facility

Expandable- Volume Types

MODULAR UNITS

CARGO TRANSPORT



The Jones, Partners' Program Container System (PRO/Con) uses 20 ft recycled shipping containers as units that can be leased or sold to homeowners as modular special function spaces for kitchens, offices, storage and other purposes.

- The system is highly customizable and allows for many different configurations:
  - Panels between the containers form "free space" glass-walled areas that vary the look of each structure and create open living spaces.
  - Other 8ft x 20ft panels form floors, walls, ceilings and roofs that can be shipped in containers used to create the rest of each house.
  - Floor panels are made of recycled wood, and roof panels are solar to provide electricity for heating and cooling.
  - Containers and panels can be reconfigured to change the homes over time as desired.

Jones, Partners:  
Architecture

PREFAB MODERN



Program Container System (Pro/ Con)

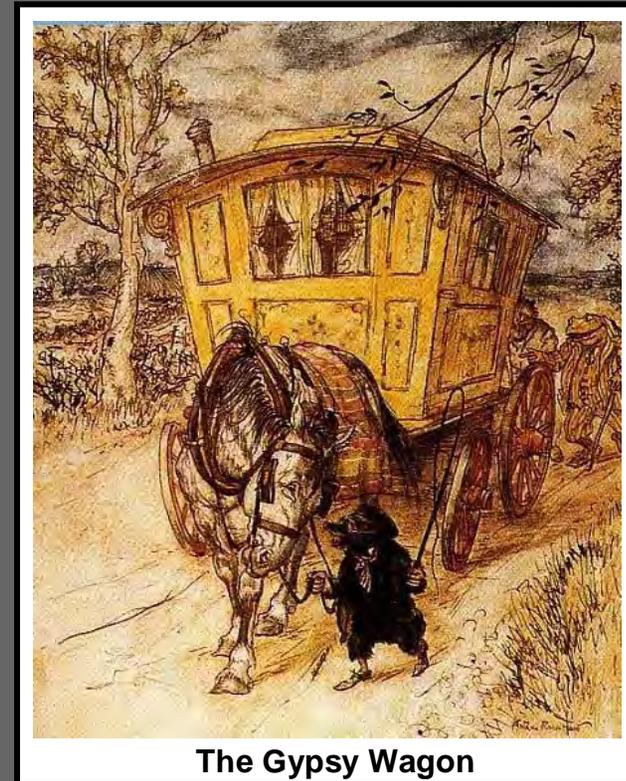
Expandable- Volume Types

MODULAR UNITS

CARGO TRANSPORT

**MOVE HOUSE**

- “Mobile homes” date back to horse-drawn Gypsy wagons that were popular during the 19th century.
- The most common type was the “bowtop”, which had a fabric roof stretched over wooden bows mounted on a four-wheeled cart or “dray”.
    - The design was very light, resembling Conestoga wagons (or “prairie schooners”) used by settlers traversing the American plains.



Fixed- Volume Types

**MODULAR UNITS**

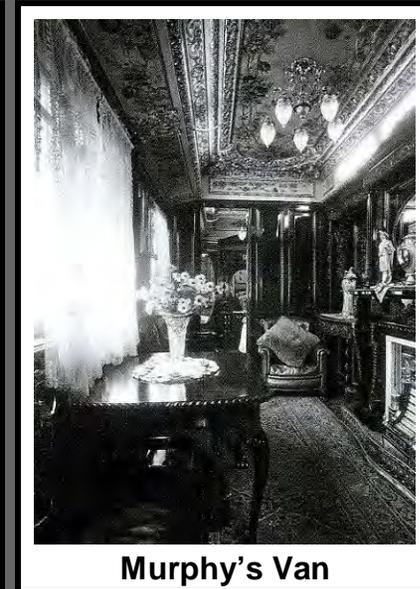
**TOWABLE ELEMENTS**

Contrasting with the modest lightweight Gypsy wagon were the ornate living and dressing vans used by performers during the late 1800s and early 1900s.

- An English showman named Walter Murphy commissioned an elaborate van to be created in 1930 from the firm of Orton and Spooner:
  - The vehicle was more than 9 meters long, and was outfitted with electric lights and a heater.
  - Living vans became fashionable among European middle classes during the early 20<sup>th</sup> century.



**Dressing Trailer**



**Murphy's Van**

## MOVE HOUSE

Fixed- Volume Types

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**MODULAR UNITS**

**TOWABLE ELEMENTS**

## MOVE HOUSE

The earliest recreational trailers were based upon living vans used by traveling showmen.

- Dr. W. Gordon Stables, vice president of the Cavaravan Club of Great Britain and Ireland formed in 1907, commissioned the creation of a personal pleasure van called “Land Yacht Wanderer”:
  - The 6-meter wide, 3.35 meter high van was pulled by two horses.
  - The interior was divided into two rooms: a saloon area that transformed into sleeping quarters, and a combined kitchen/washroom at the rear.
  - Wanderer was built largely of solid mahogany, and its weight sometimes proved too heavy for the horses on hills.
  - Dr. Stables was joined on his travels by a coachman, a valet, his dog and a parrot.



**Dr. Stable's Land Yacht Wanderer**

Fixed- Volume Types

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**MODULAR UNITS**

**TOWABLE ELEMENTS**

**MOVE HOUSE**

The advent of automobiles and highway development established a trend for motoring holidays to boom, and trailer tourism had become such a popular pastime by 1936 that camping trailer parks were established throughout the US.

- In 1932 Wally Byam unveiled the “Clipper”, the first in a long series of Airstream trailer designs based upon aircraft technology featuring a rivet-fastened aluminum body and bullet-shaped nose that became popular and famous.



**The First Airstream Trailer (1932)**



**Small Airstream Trailer**

**Fixed- Volume Types**

**MODULAR UNITS**

**TOWABLE ELEMENTS**

**MOVE HOUSE**



Fixed- Volume Types

**MODULAR UNITS**

**TOWABLE ELEMENTS**



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MOVE HOUSE

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DON'T WAIT! See this newest creation by one of the world's greatest mobile home manufacturers at your RICHARDSON dealer TODAY, or write for complete information.

Fixed- Volume Types

MODULAR UNITS

TOWABLE ELEMENTS



The small Airstreams with such features as four bunks, a tubular metal dinette, kitchen and advanced heating and ventilation systems became so popular that the company struggled to meet demand.

- Other manufacturers with larger and relatively less expensive models entered the marketplace, including the Spartan Aircraft Company:
  - Seasonal and itinerant workers in the US began adopting recreational vehicles as temporary homes during the 1930s depression.
  - During World War II the need to create instant communities around munitions factories, shipyards and other manufacturing works led to rapid development of trailer parks.
  - Trailer parks continued to grow as soldiers returning from overseas needed affordable homes, creating markets for all-weather, year-round units.

MOVE HOUSE

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Fixed- Volume Types

MODULAR UNITS

TOWABLE ELEMENTS

The Caravan prototype was one of five winning entries to a competition sponsored by the Museum of Contemporary Art in Sydney, Australia in 1991.

- The design is reminiscent of Airstream trailers manufactured in the US during the 1940s:
  - A lightweight aluminum aerodynamic semi-monocoque shell projects over the towing car to minimize overall length, achieve a low drag coefficient and provide a small turning radius.
  - Solar panels on the roof produce electricity for user functions.

Jan Kaplicky

FUTURE SYSTEMS



**The Caravan**

Fixed- Volume Types

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**MODULAR UNITS**

**TOWABLE ELEMENTS**



The Federal Emergency Management Agency (FEMA) has purchased several thousand trailers to provide housing for victims of hurricanes and other disasters.

- Of about 135,000 trailers ordered for families displaced by hurricane Katrina, nearly 11,000 remained parked and unused at a Gulf Coast airport:
  - Many of these units remained unused due to regulations that prohibit trailers from being located in flood plains.
  - Residents in numerous communities also objected to the resulting new trailer parks as eyesores that would decrease property values in their areas.
  - Residents have also been concerned that the presence of additional trailer parks will result in higher neighborhood crime rates.



**FEMA Trailers**

**Fixed- Volume Types**

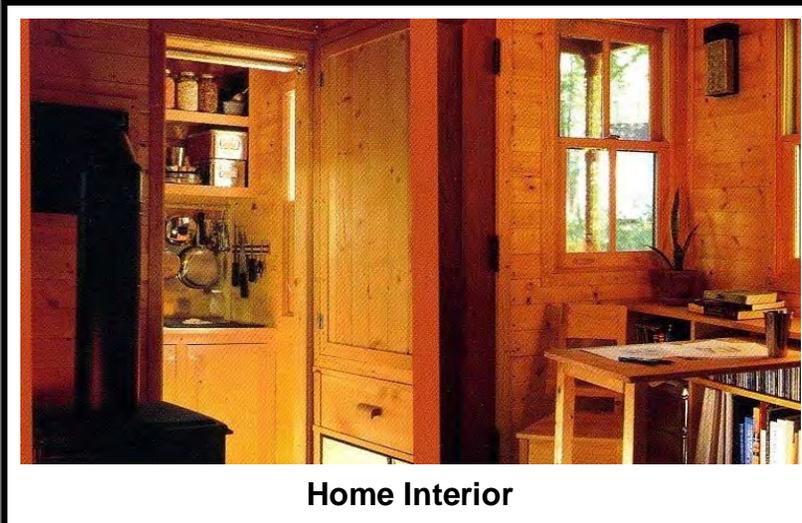
**MODULAR UNITS**

**TOWABLE ELEMENTS**



Jay Shafer, an Iowa-based designer and builder created his Tumbleweed house using conventional wood construction.

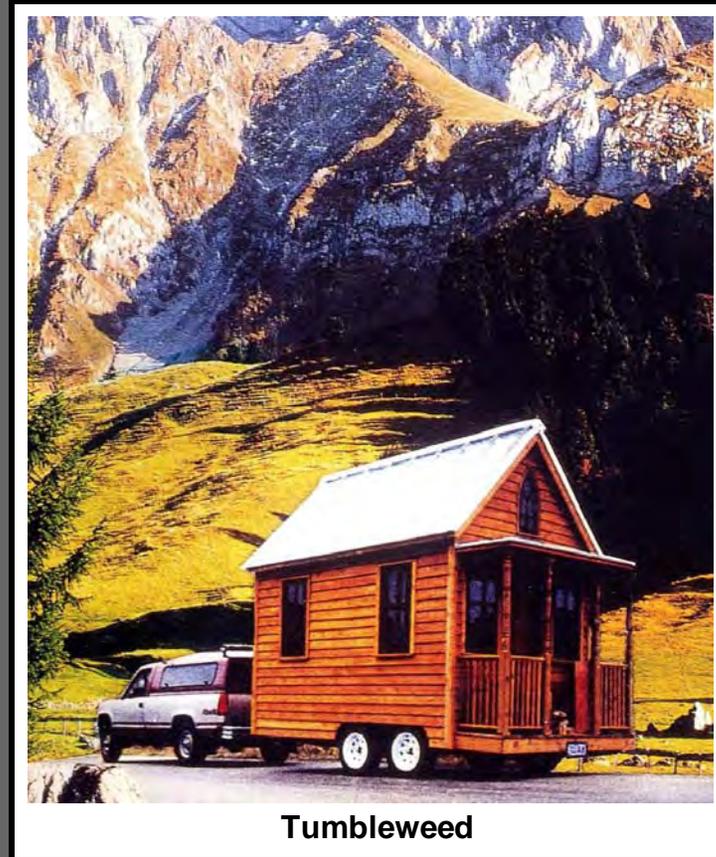
- Mounting the home on wheels circumvents minimum size standards imposed by many urban and suburban communities for permanent structures.



**Home Interior**

Jay Shafer

**MOVE HOUSE**



**Tumbleweed**

**Fixed- Volume Types**

**MODULAR UNITS**

**TOWABLE ELEMENTS**

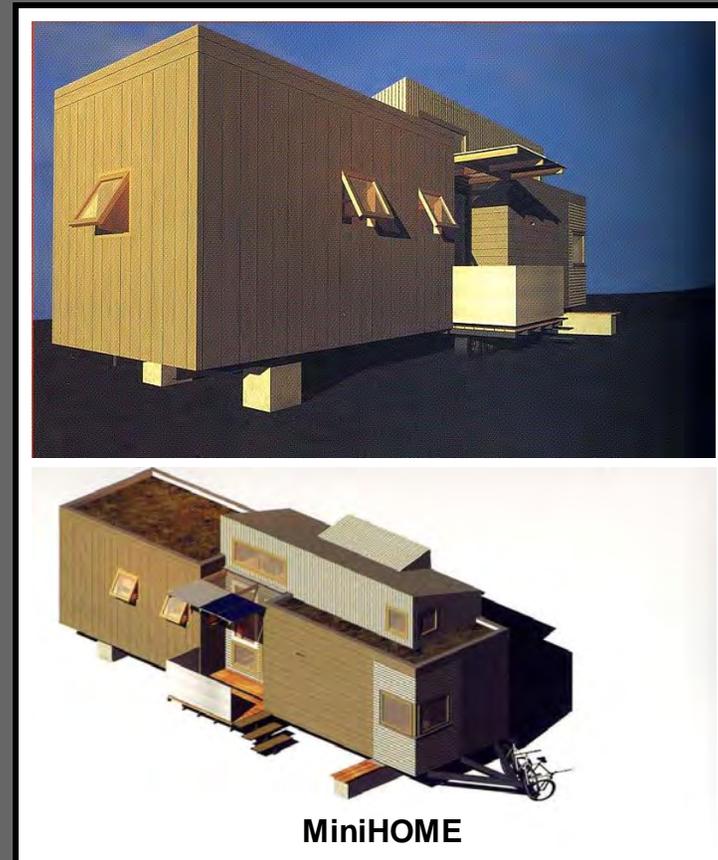


R.R. Thomson

MOVE HOUSE

R.R. Thomson, a Canadian designer, developed his MiniHOME trailer in 2004:

- The 9.75m x 2.6m x 4m structure does not have an expandable interior, but does provide an extendable entrance deck and canopy:
  - Solar panels are used to provide power for highly efficient LED-augmented interior lighting systems.
  - A platinum catalytic heating unit avoids harmful exhaust gases typically produced by propane fuel.
  - Construction is superior to conventional mobile home fabrication standards.



MiniHOME

Fixed- Volume Types

MODULAR UNITS

TOWABLE ELEMENTS



The M-House (pronounced “mouse”) is a full kit house that can be ordered online with a customizable exterior finish.

- The two-bedroom home can be ordered either as a shell or as a complete unit with interior finishes and fixtures:
  - Exterior finish options include plain aluminum, printed aluminum with checks or stripes, cedar strips or shingles, or painted tongue-and-groove wood.
  - The home comes in two pieces that are “zipped together” on the site.
  - A self-supporting steel structure enables a 1,000ft<sup>2</sup> space without interior walls.

Tim Pyne

PREFAB MODERN



**The M-House**

Fixed- Volume Types

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**MODULAR UNITS**

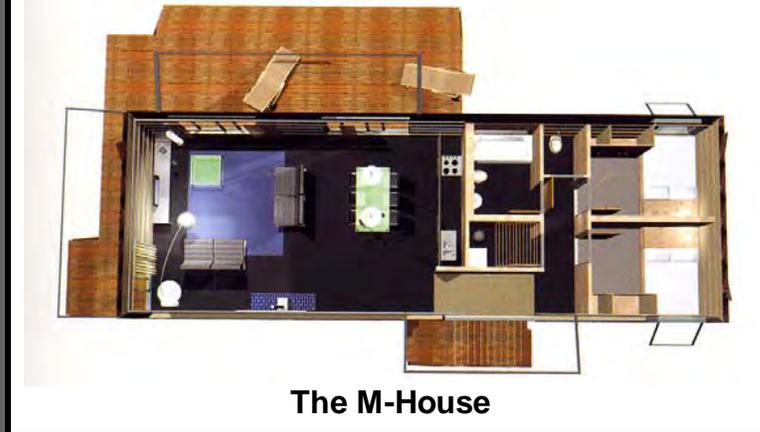
**TOWABLE ELEMENTS**



PREFAB MODERN

C-75

Tim Pyne



The M-House

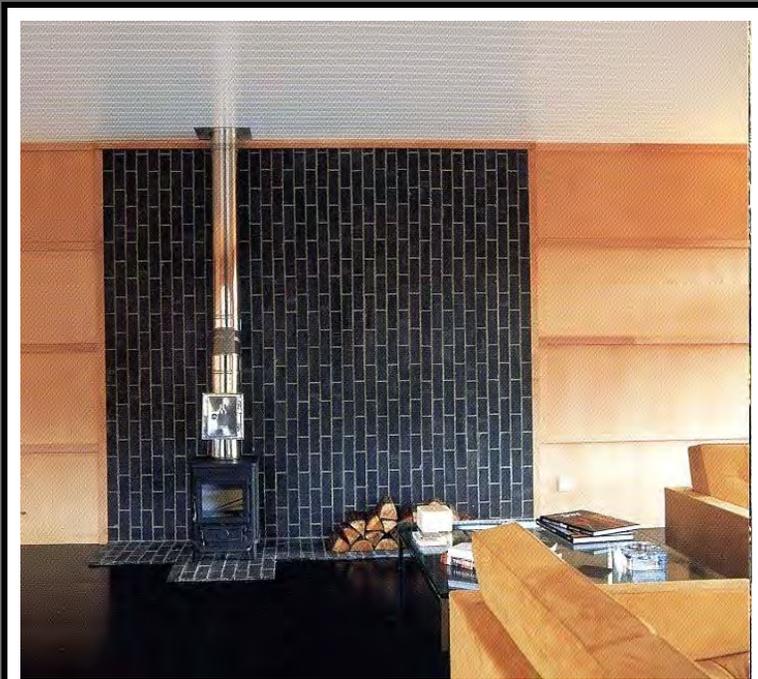
Fixed- Volume Types

MODULAR UNITS

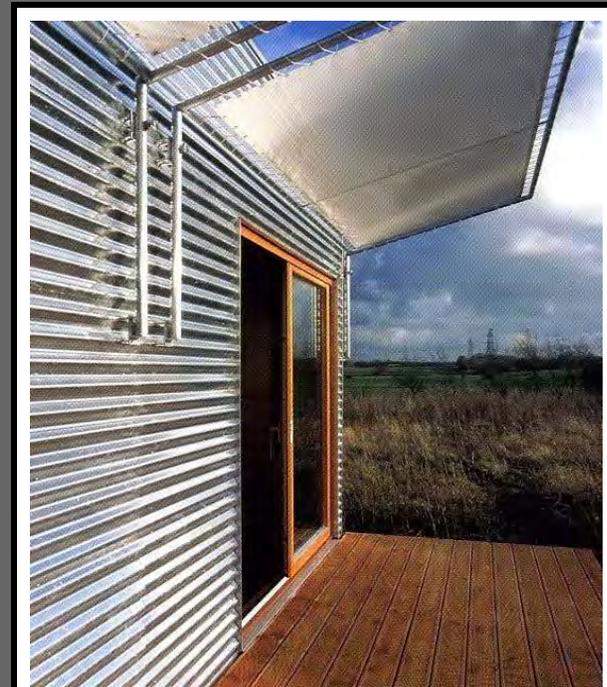
TOWABLE ELEMENTS

Tim Pyne

PREFAB MODERN



Interior



The M-House

Fixed Volume Types

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MODULAR UNITS

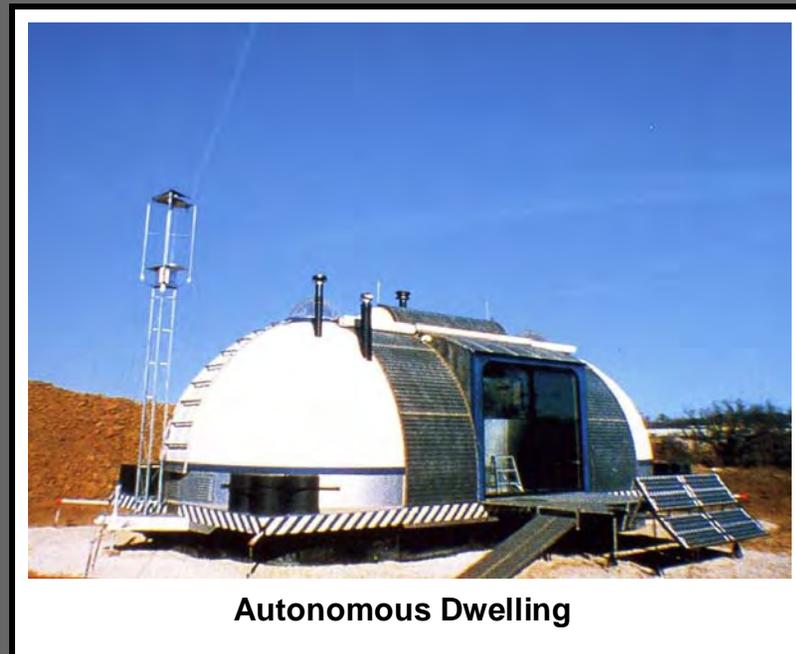
TOWABLE ELEMENTS

Michael Jantzen's Autonomous Dwelling was developed in 1999 for a real estate developer who spent much of his time living on construction sites that were not yet hooked up to power grids.

- The dwelling is an advanced mobile home which generates its own power from the sun and wind:
  - The quarter-spheres that form module ends are two halves of a metallic dome used to cap tops of grain silos.
  - Self-sufficiency is an essential goal in Jantzen's work.

Michael Jantzen

MOVE HOUSE



Fixed- Volume Types

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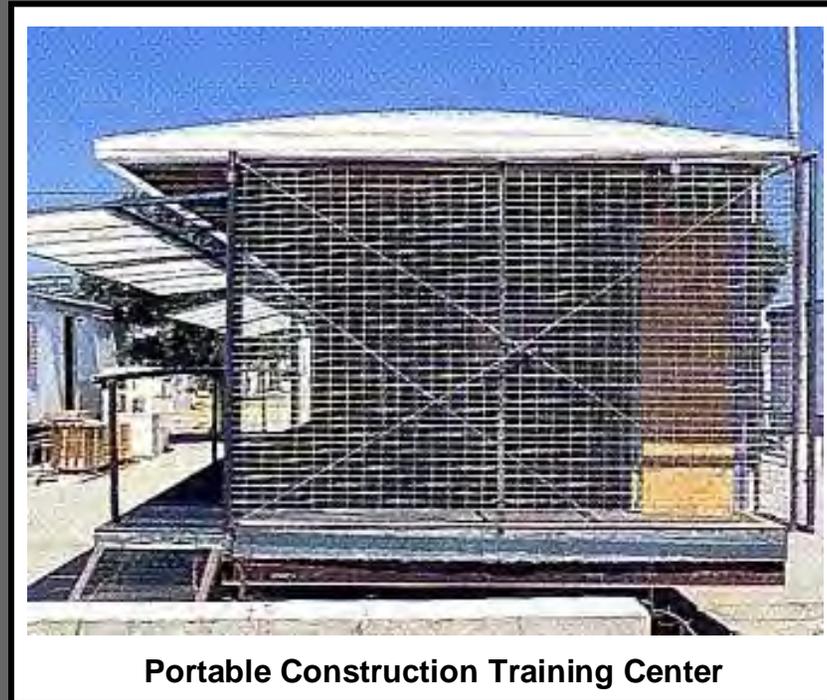
**MODULAR UNITS**

**TOWABLE ELEMENTS**

**OFFICE OF MOBILE DESIGN (OMD)**

OMD conceived a Portable Construction Training Center design for the Venice, California Community Housing Corporation, an organization that develops and maintains affordable housing for disadvantaged low-income individuals.

- The 14ft X 16ft trailer provides a hands-on classroom for student trainees to learn construction skills:
  - A 14ft X 14ft meeting space at the threshold exhibits construction example boards.
  - Like a large porch, one entire length of the trailer folds open to expose independent interior workstations.
  - An operable translucent roof panel provides shade and regulates the natural flow of hot and cold air.
  - The far end folds open to expose a wood shop where tools can be disengaged to roll outside.



**Portable Construction Training Center**

**Fixed- Volume Types**

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**MODULAR UNITS**

**TOWABLE ELEMENTS**

**OFFICE OF MOBILE DESIGN (OMD)**



**Portable Construction Training Center**

**Fixed- Volume Types**

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**MODULAR UNITS**

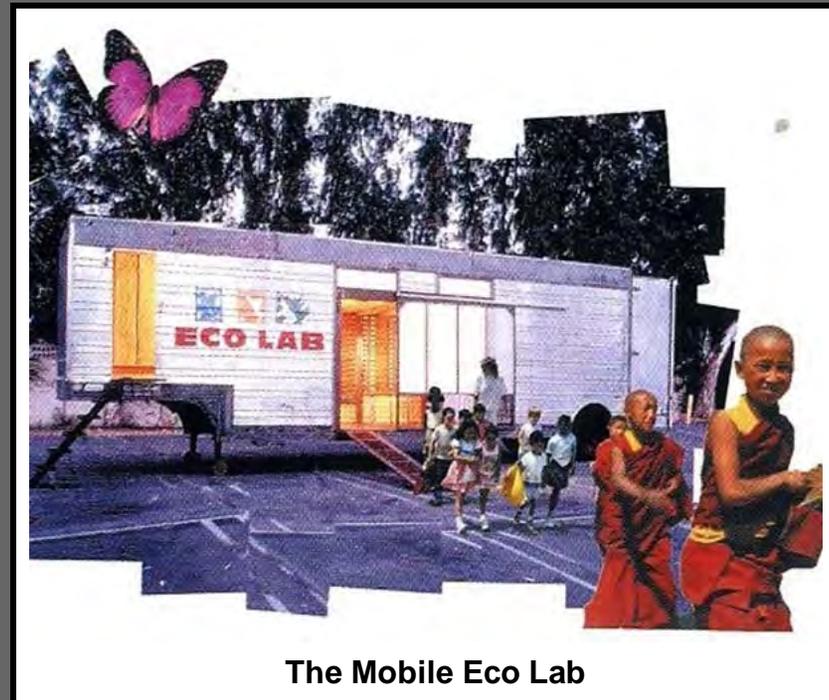
**TOWABLE ELEMENTS**



OMD's Mobile Eco Lab was built in collaboration with the Hollywood Beautification Team to support educational programs aimed at improving the Los Angeles Hollywood community.

- The 8ft x 35ft trailer travels throughout the area to inform K-12 school children about environmental issues:
  - Elevated walkways fold down and slide out of the trailer's body to expose interior areas.
  - Children can access the lab via a set of folding stairs that are lowered by a nautical winch to enter a multimedia antechamber that offers exhibits, a video program and a computer for web-surfing.
  - A stage-like platform rolls out of wheel wells where children learn to water tree saplings.

## OFFICE OF MOBILE DESIGN (OMD)



**The Mobile Eco Lab**

Fixed- Volume Types

**MODULAR UNITS**

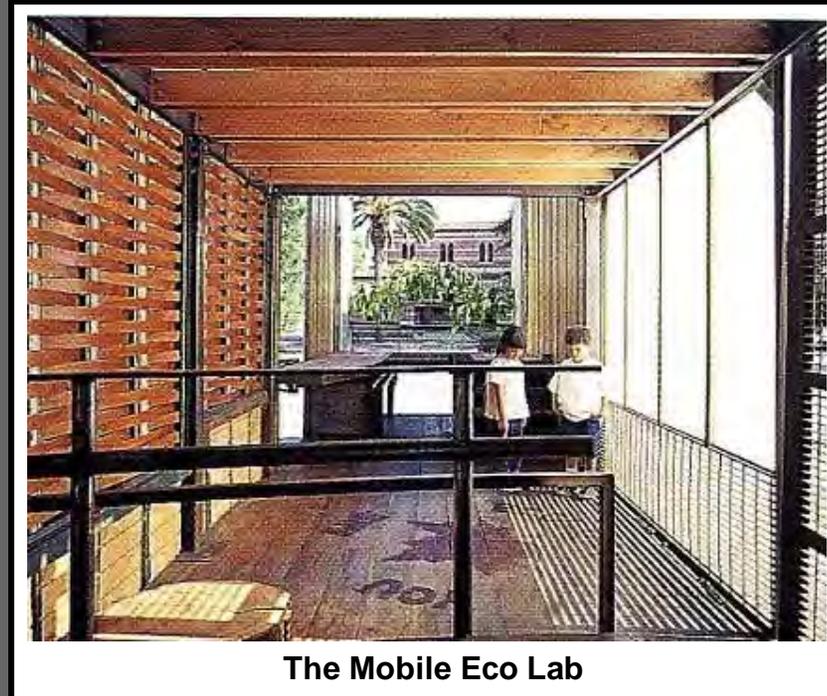
**TOWABLE ELEMENTS**



The Eco Lab was constructed using an 8ft x 35ft donated cargo trailer and cast-offs taken from Hollywood film sets. Woven wooden slats provide transparency along a wall for natural illumination.

Functioning as a traveling studio, local artists collaborate with children to design façade-sized murals to replace graffiti at inner-city schools.

## OFFICE OF MOBILE DESIGN (OMD)



**The Mobile Eco Lab**

Fixed- Volume Types

**MODULAR UNITS**

**TOWABLE ELEMENTS**



In the early 1900's, Volvo commissioned the Scandinavian Apicella design firm to create a family of portable pavilion units that could be used to market their automobiles.

- Although the structures were to be built on different sized truck beds, the objective was to give the appearance of permanence rather than that of a temporary trailer:
  - The smallest is a promotional facility that functions as an office and hospitality space, using a flatbed trailer towed by a large van.
  - A merchandize unit serves as a shop to sell Volvo racing tie-in products (clothes, books and souvenirs) built on a large articulated lorry trailer.
  - A multifunction pavilion also built on a large articulated lorry trailer could be used as an independent hospitality space or as the reception entrance to a much larger rented commercial structure.



**Volvo Car Mobile Marketing Units**

## PORTABLE ARCHITECTURE

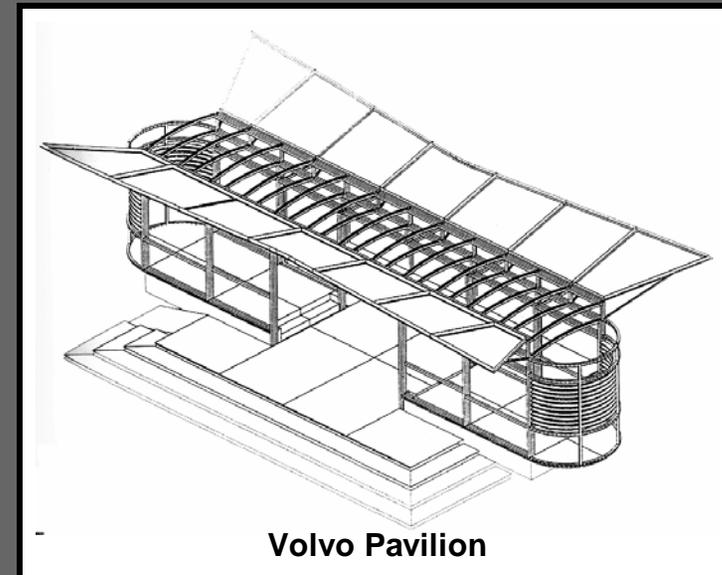
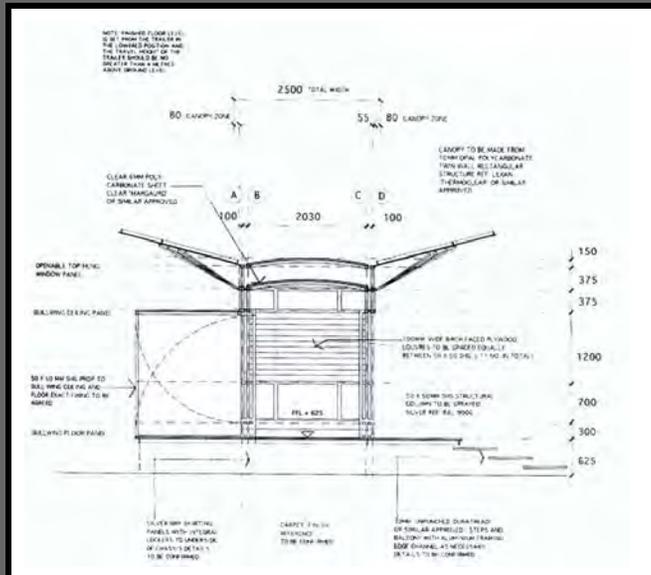
Fixed- Volume Types

**MODULAR UNITS**

**TOWABLE ELEMENTS**



**PORTABLE ARCHITECTURE**



**Volvo Pavilion**

All units share the same basic construction. A silver-painted 50 mm square hollow steel structural framework supports an aluminum curtain wall system with clear and etched polycarbonate panels.

Roof sections consist of curved polycarbonate panels with opaque, glass-reinforced plastic sections at the double-curved ends. Fold-out and fold-down elements provide canopies and decks.

**Fixed- Volume Types**

**MODULAR UNITS**

**TOWABLE ELEMENTS**

## OFFICE OF MOBILE DESIGN (OMD)

OMD's Mobile Event City Architecture (MECA) concept provides a means to support multi-day outdoor events, including charities associated with AIDS, breast cancer, world hunger and other causes.

- The goal is to offer structures that can be grouped together into encampments that are easily relocatable, adaptable to varying site conditions, climate controlled, well-lit and visually striking:
  - Different master plan schemes are possible, including a centralized "town square" configuration, a "Main Street" linear corridor approach, or combinations of these options.
  - The structures would be situated along an elevated boardwalk that serves as a connection thoroughfare.



**Mobile Event City Architecture**

Expandable- Volume Types

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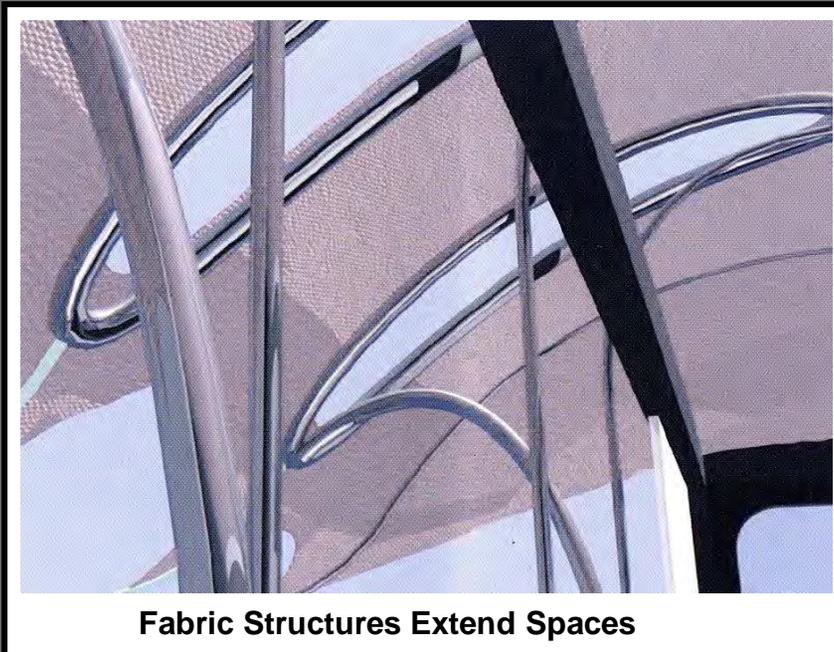
**MODULAR UNITS**

**TOWABLE ELEMENTS**



Existing truck types would be modified to incorporate tensile fabric structures which are weather-resistant and easy to deploy/ relocate.

The fabric structures can unfold, slide open, pivot and pull apart to expand floor area and to form walls and overhangs.



**Fabric Structures Extend Spaces**



**OFFICE OF MOBILE DESIGN (OMD)**

**Mobile Event City Architecture**

**Expandable- Volume Types**

**MODULAR UNITS**

**TOWABLE ELEMENTS**



## PORTABLE ARCHITECTURE



The Apicella firm designed a mobile pavilion for the UK Trustee Savings Bank to support staff training and hospitality events. The pavilion was required to be erectable in two days by four people at a cost of no more than 4,000 pounds (including transportation).

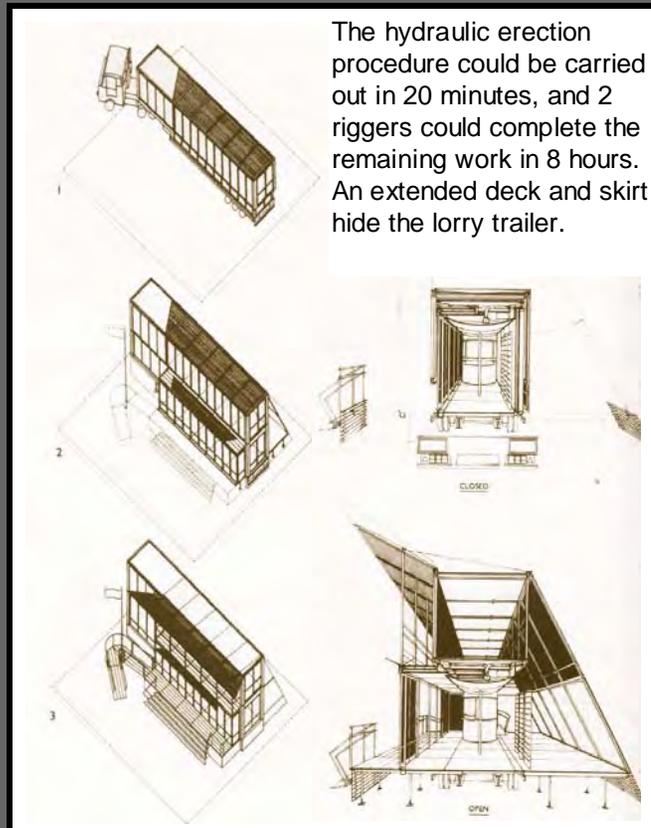


**TSB Mobile Bank and Hospitality Facility**

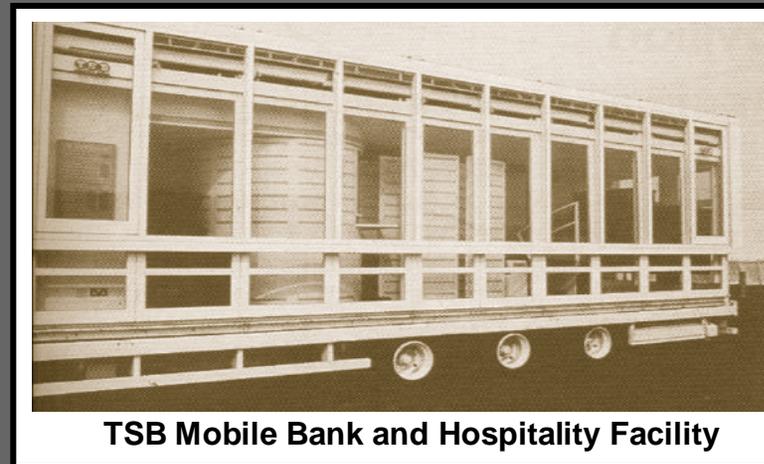
Expandable- Volume Types

**MODULAR UNITS**

**TOWABLE ELEMENTS**



## PORTABLE ARCHITECTURE



Apicella's design was based upon a 40ft long articulated lorry trailer platform that served as the lower floor.

Four hydraulic rams lifted an internal telescoping structure directly above the lower enclosure to create an upper storey.

Terraces and canopies were then unfolded and pushed out from the main structure to articulate the façade.

## Expandable- Volume Types

## MODULAR UNITS

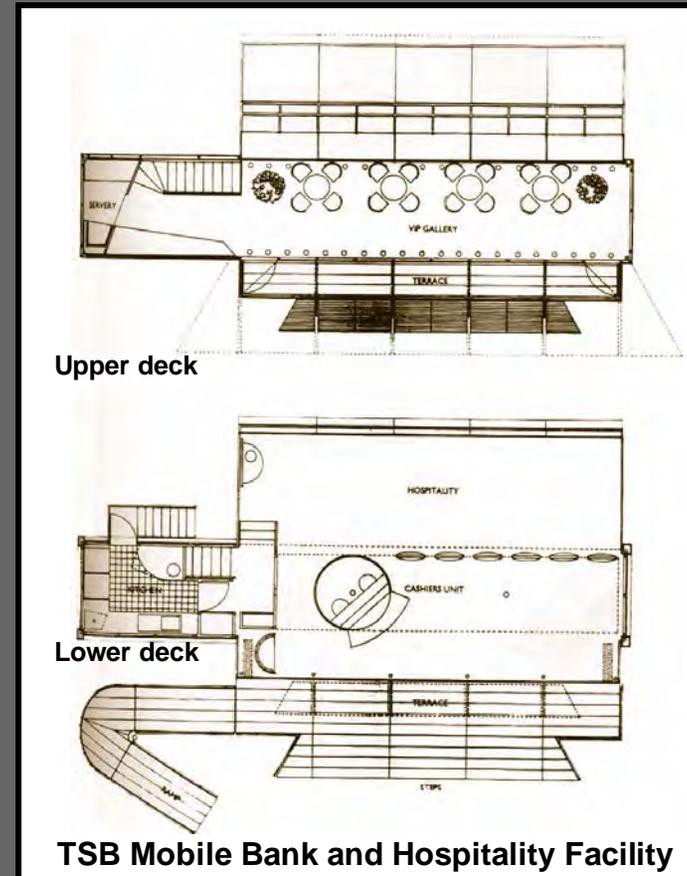
## TOWABLE ELEMENTS



## PORTABLE ARCHITECTURE

Once in position, the expanded structure was locked into place and the floors were leveled and stabilized with foldout adjustable legs.

- The completed facility provided a number of special design features:
  - A cashier's unit on the lower floor could be rotated through 180 degrees to allow this area to be used in a number of different ways.
  - An upstairs hospitality suite with access to an open-air balcony was serviced via a dumbwaiter from the lower level kitchen.
  - A glazed skin adjacent to the lower floor terrace was fully retractable in good weather.
  - A support vehicle carried furniture, erection tools and components, and an on-board generator for power.



Expandable- Volume Types

MODULAR UNITS

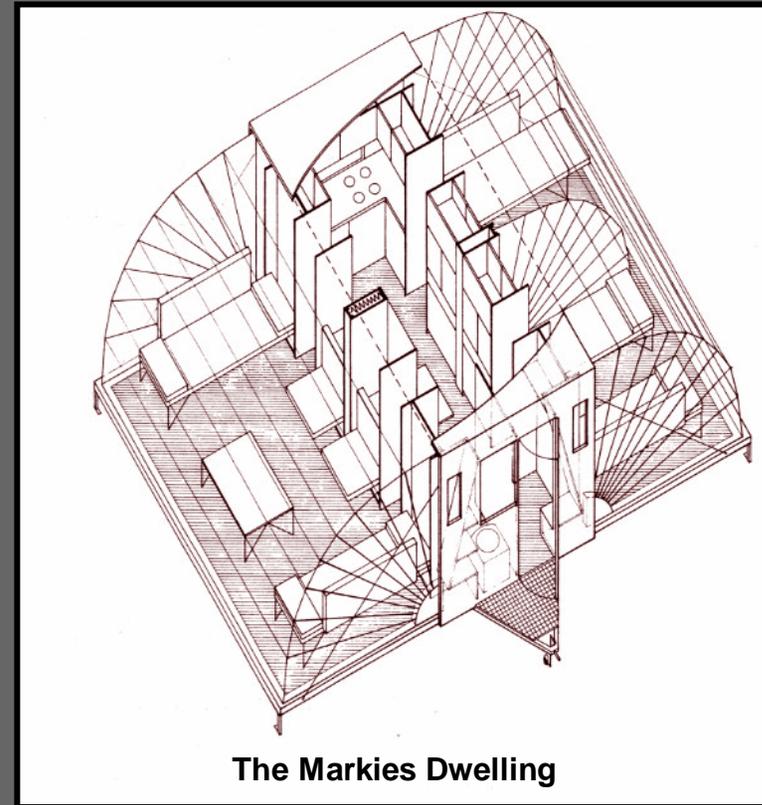
TOWABLE ELEMENTS



## PORTABLE ARCHITECTURE

Developed in the Netherlands, the Markies habitat was conceived as a comfortable permanent mobile dwelling that can be easily moved with all furnishing and fittings as integral parts of the structure.

- The floor area is tripled when the 7ft x 14ft unit side panels are deployed, increasing the width to 21 feet.
  - Entry is through a small hallway with coat storage at the end near the towing hitch.
  - All primary facilities including the bathroom and kitchen are incorporated into the main chassis and are accessible in the traveling position.
  - A fold-down area to the left of the entrance contains two bedrooms, each with a door.
  - A fold-down living area to the right provides a living space with a fold-down dining table incorporated into a storage unit with swing-out dining stools.



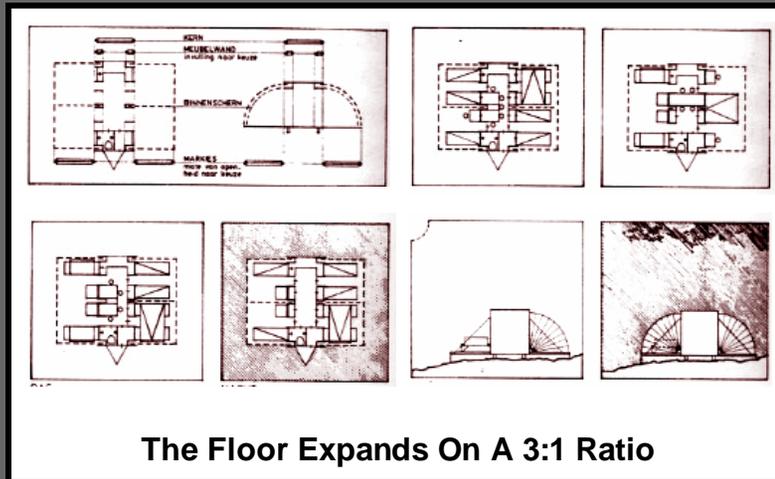
**The Markies Dwelling**

Expandable- Volume Types

**MODULAR UNITS**

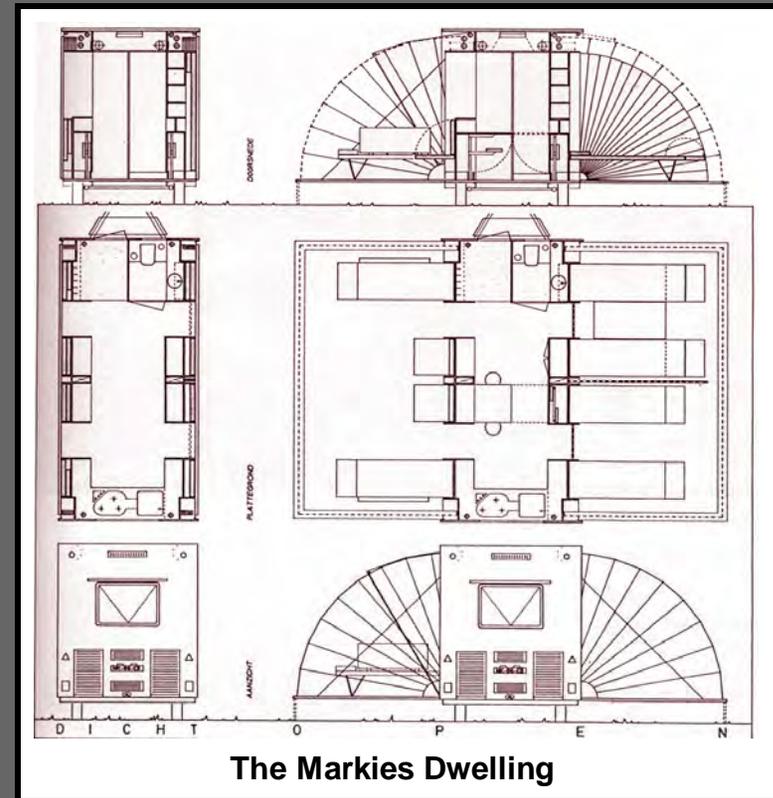
**TOWABLE ELEMENTS**

Markies was built in 1992 on a conventional steel trailer chassis. The habitat structure is comprised of a steel frame with 15 mm thick poplar panels coated with vinyl. The deployable accordion-type folding walls rapidly drop down with the press of a button.



**The Floor Expands On A 3:1 Ratio**

**PORTABLE ARCHITECTURE**



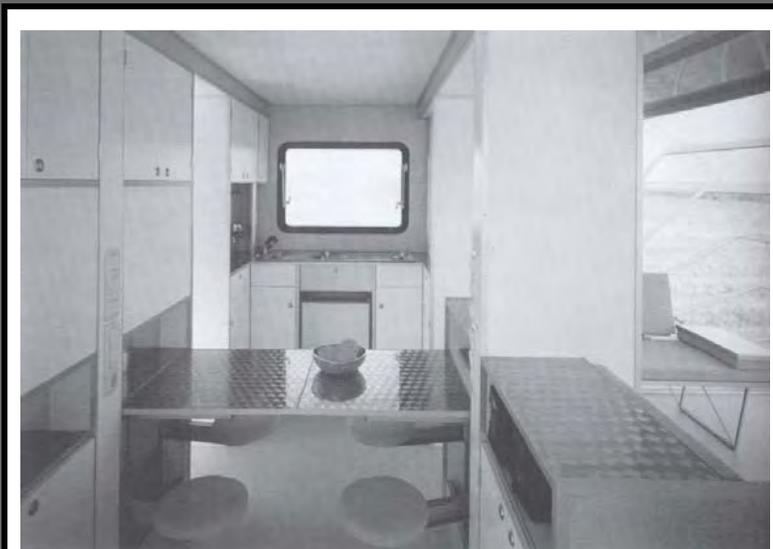
**The Markies Dwelling**

**Expandable- Volume Types**

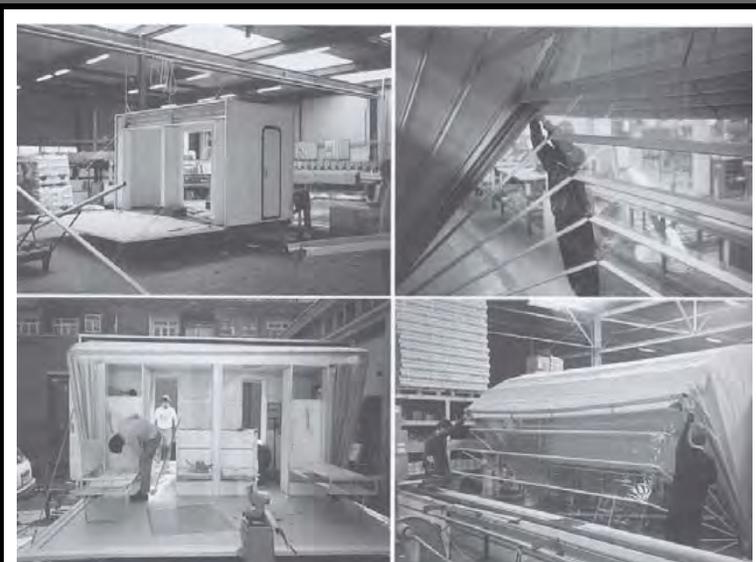
**MODULAR UNITS**

**TOWABLE ELEMENTS**

**PORTABLE ARCHITECTURE**



**Primary Facilities are Integrated Into the Chassis**



**The Markies Dwelling**

**Expandable- Volume Types**

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**MODULAR UNITS**

**TOWABLE ELEMENTS**

**PORTABLE ARCHITECTURE**



**Deployment of the Markies Dwelling**

**Expandable- Volume Types**

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**MODULAR UNITS**

**TOWABLE ELEMENTS**



Exuba is a luxurious motor home built on the chassis of an Ashok Leyland Cargo Truck (India).

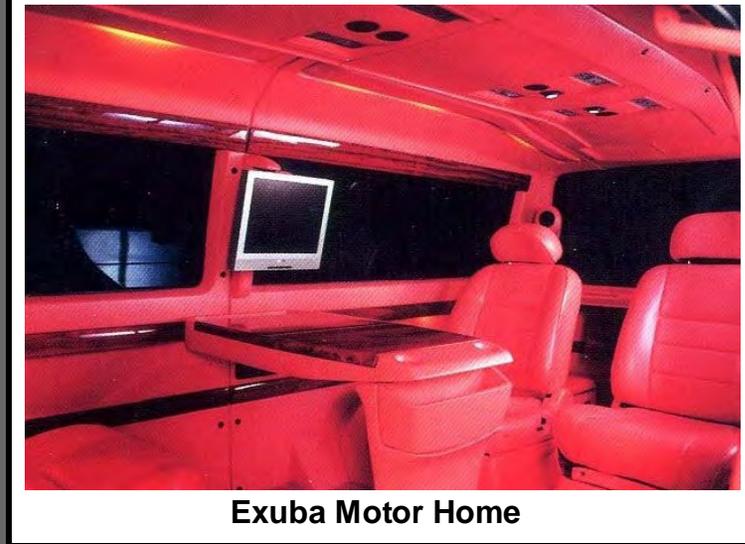
- The interior provides a lounge area, chemical toilet, pantry, sleeping quarters and a bar.
  - Onboard amenities include a home entertainment system, personal computer, refrigerator and a microwave oven.
  - The structure is a metal framework sheathed in aluminum panels that are coated with a plastic finish.



**Exuba Motor Home**

Dilip Chhabaria,  
DC Designs

C-94  
**MOVE HOUSE**



**Exuba Motor Home**

**Fixed- Volume Types**

**MODULAR UNITS**

**SELF-TRANSPORTING**



Canadian architect R.R. Thomson developed his Vanzilla mobile home design in 2001 by modifying a GMC step van.

- Thomson bought the vehicle and completely renovated it with a student loan:
  - Solar panels on the roof provide electricity for LED-augmented lighting.
  - He installed platinum catalytic heating systems that are well suited for small spaces because it does not emit harmful exhaust gases due to the way propane fuel is processed.
  - Thomson lived in the modified delivery van with his wife and daughter in Vancouver for about a year.

R.R. Thomson

MOVE HOUSE



Vanzilla

Fixed- Volume Types

MODULAR UNITS

SELF-TRANSPORTING



## OFFICE OF MOBILE DESIGN (OMD)

OMD's iMobile was designed as a moving store which can bring shopping opportunities directly to consumers.

- The unit can be parked in commercial lots, neighborhood parks or at industry convention sites as a self-contained promotional vehicle:
  - The facility serves as a roving online portal for accessing global communications networks and announcing the latest computer systems, peripherals, hardware and software.
  - Six individual work pods are outfitted with computer setups, which are programmable and adaptable for product promotion or sampling.



**The iMobile**

Fixed- Volume Types

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**MODULAR UNITS**

**SELF-TRANSPORTING**



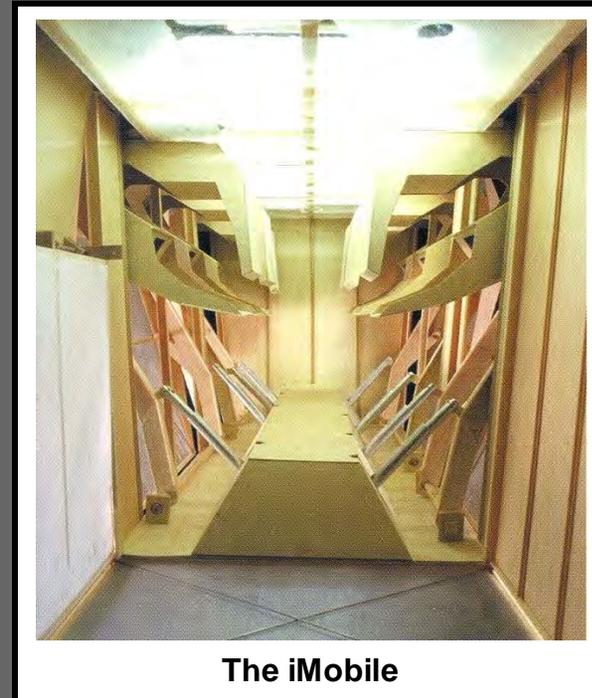
Hinged iMobile awnings hinge upward to provide sunscreens, and decks hinge downward to create exterior exhibit displays.

Internal computers and other devices can fold into walls during transport and provide a variety of plug-in opportunities to change out or add equipment.

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**MODULAR UNITS**

**OFFICE OF MOBILE DESIGN (OMD)**



**The iMobile**

**Fixed- Volume Types**

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**SELF-TRANSPORTING**



This huge 10 meter long home built on the chassis of a fire truck (Australia) provides a comfortable living/work space that can be occupied for long periods of time.

A rugged foundation gives the vehicle excellent off-road capabilities across terrain that would destroy any regular motor home.



**Jumbo Motor Home on a Fire Truck Chassis**

Rob Gray

MOVE HOUSE



**Wothaleizat**

Fixed- Volume Types

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**MODULAR UNITS**

**SELF-TRANSPORTING**

Rob Gray

MOVE HOUSE

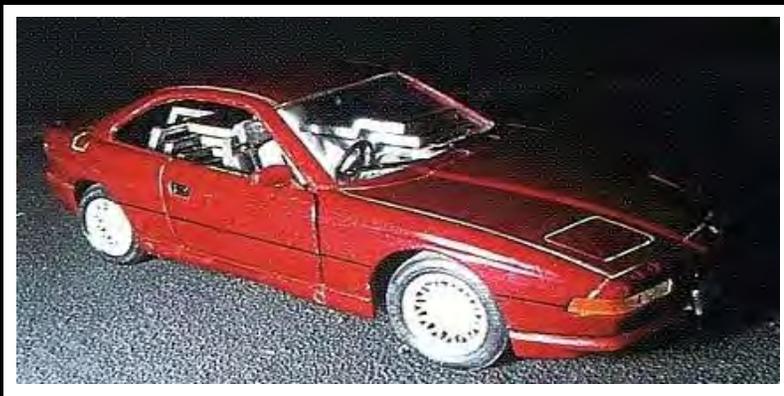


Wothaleizat

Fixed- Volume Types

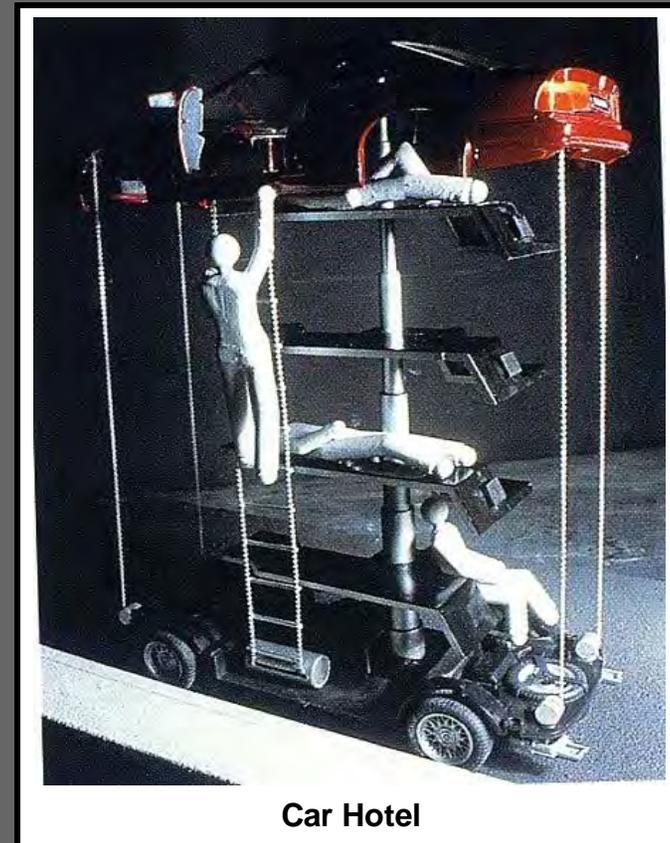
**MODULAR UNITS**

**SELF-TRANSPORTING**



This concept proposes that a conventional car be converted from a carriage for passengers to a multi-storey dwelling unit.

- The middle of the car contains a hydraulic piston that lifts attached stackable bed/seat units:
  - Each floor consists of a bed formed into a pillow at one end and a seat on the other.
  - Next to each seat is a television directed toward the floor below.
  - A chain ladder deployed from a spool on the car floor provides vertical access.
  - The shell of the car separates and is hydraulically lifted to provide a roof over the otherwise exposed levels.



**Car Hotel**

**Expandable- Volume Types**

**MODULAR UNITS**

**SELF-TRANSPORTING**



The Combinatoria (Germany) was created by Michael Saup, a Digital Media Arts Professor, to transport and support “nomadic workshops” in remote off-road locations.

- The vehicle incorporates living and sleeping quarters along with a removable kitchen and long table which doubles as a dining area and workstation sheltered by metal fencing and a large canopy.

Michael Saup

MOVE HOUSE



The Combinatoria

Expandable- Volume Types

MODULAR UNITS

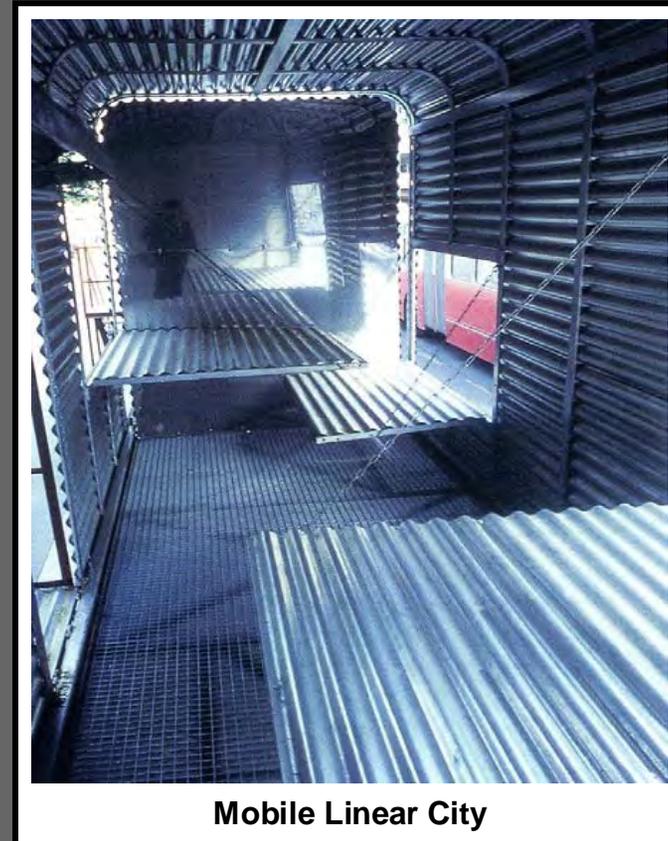
SELF-TRANSPORTING



When the truck is parked, a line of telescoping units can be pulled out of its trailer.

- Each unit slides on a track attached to the walls of the next larger unit:
  - As each unit slides out, its support legs fold down and are fixed to the ground and the truck is then driven forward to release the element.

ACCONCI STUDIO



**Mobile Linear City**

Expandable- Volume Types

**MODULAR UNITS**

**SELF-TRANSPORTING**



- The housing units are sheathed in corrugated steel cut into sections which are hinged to enable the sections to fold down:
  - A gangplank drops down outside, and a ladder is deployed onto the ground from underneath to provide surface access/egress.
  - End walls fold down to create a back porch, along with deployable ladders to provide an additional access point.
- Each housing unit contains basic living amenities:
  - Interior wall panels pivot down to provide a table, bench bed and shelf.
  - Hinged wall partitions enclose and provide access to a stove, refrigerator, toilet and shower.
  - The last unit (the smallest) provides electrical power, air conditioning and water supply/waste utilities.



**Mobile Linear City**

**Expandable- Volume Types**

**MODULAR UNITS**

**SELF-TRANSPORTING**