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Aquatecture
Macro-design Projects on the Theme: "Water"
Mobile Offshore Industry

Edited by Charles L. Owen

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Three additional **Aquatecture** project reports are available under the subtitles:
- **Floating Fields**
- **CrossRoads in the Sea**
- **Patterned Energy**

Detailed information on the Structured Planning process used for this project can be found in papers by Prof. Charles Owen on the Institute of Design web site: www.id.iit.edu

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Aquatecture. Macro-design Projects on the Theme "Water": Floating Fields
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Preface

Mankind is inextricably bound to the water. Beyond our own obvious physiological needs, there are its associations with other life forms of concern to us, its importance as a medium for transportation and commerce and, above all, its very omnipresence. Three quarters of the Earth's surface is covered by water, and a great percentage of the world's population lives close to large bodies of water.

The contrast between development of the resources of land and sea, however, is sharp. The disparity suggests that, as we near the new millennium, we consider thoughtfully how to extend to the seas the understanding we have gained in developing the land for human habitation and support of our societies. Activities that were conceived for and evolved on land might now be better conducted on the waters, given the maturation of our technological knowledge and the crowding of our land base.

Aquatecture is a conceptual systems design project. Drawing on the computer-supported techniques of Structured Planning, it explores possibilities for uses of water resources for food production, transportation, energy development and manufacturing. Four subprojects: **Floating Fields, CrossRoads in the Sea, Patterned Energy** and **Mobile Offshore Industry**, deal individually with these subjects. In separate project reports, each speculates on how a "macrodesigned" environment might be developed using known technology to expand the uses of the seas, lakes and rivers as space, media and sources of energy, food and raw materials. This report describes **Mobile Offshore Industry.**

All four projects were done in the Fall 1986 Systems and Systematic Design course at the Institute of Design. This course is the final course in a three-course sequence for product design students beginning with Product Design, continuing with Environmental Design, and ending with the Systems and Systematic Design course. The Systems course is concerned with products working in concert to achieve goals; the development of comprehensive design concepts; the problems of teamwork in design; and the use of systematic, computer-supported design techniques (Structured Planning) for handling complex problems.

The topic for the fall 1986 course was the Japan Design Foundation's Third International Design Competition. Within the competition theme of "water", four study areas were set out: food production, transportation, energy and materials processing. Research in these areas evolved projects, collectively entitled "Aquatecture", which explore visions for uses of the oceans, lakes and rivers.

The projects were completed in four months and submitted to the competition in January, 1987. From a field of 2,281 entries representing 58 countries, 1,144 projects were actually submitted from professionals and students in 48 countries. All four of the Institute of Design projects survived the first round to be among 59 finalists. After another month of work to prepare final presentations, a second submission was made in June. Final competition results were announced in August: the four Aquatecture projects were together awarded the Grand Prize of 10,000,000 yen ($78,500). The award, made in Osaka on October 30, 1987, marked the second time in three competitions that Institute of Design students had won the Grand Prize.

The projects received considerable attention in the world press. Perhaps the best presentation of them was in the Italian international magazine of architecture: ***L'ARCA***. Its April 1988 issue (No. 15) contains a ten page article with a number of drawings and color photographs.

Charles L. Owen, Advisor and Editor

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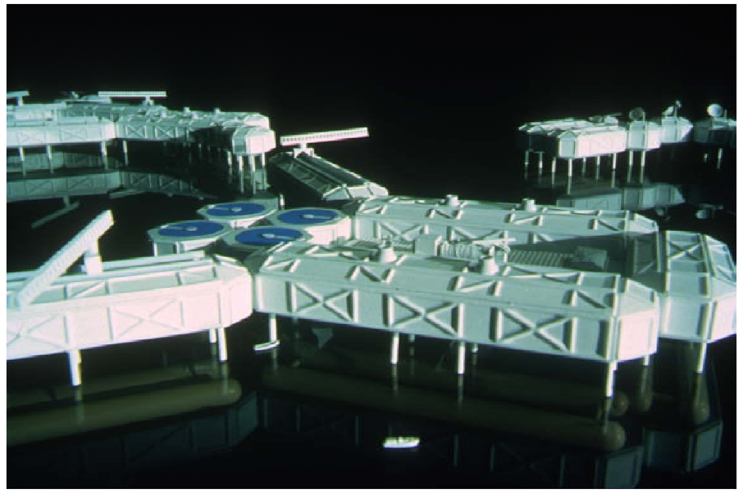

Figure 1 **Mobile Offshore Industry**
Large, general purpose SWATH modules augmented with auxiliary and special-function modules can be assembled into specialized "factories" for industrial use at sea—offshore mining shown here.

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Mobile Offshore Industry

Overview

A strong case can be made for moving industry onto the water. Because of the need for massive quantities of raw materials and the requirement for distributing large finished products, many industries traditionally have located as near as possible to waterways. In a world economy, raw materials and products are frequently seaborne during some portion of their transit. "Mobile Offshore Industry" reduces discontinuities. Factories on the sea can travel to sites where labor and materials are in favorable supply, or where products must be supplied to just-in-time schedules. Materials processing can be conducted where the materials are: off remote shores, over sea bottoms, near fishing fleets or with other aquatectural structures such as a Floating Fields food production facility. Demonstration factories can bring manufacturing to developing urban centers. Plant configurations can almost exactly follow flowcharts—a practical metaphor virtually unobtainable in crowded urban environments.

Elements of the Mobile Offshore Industry system are modular "aquatectural" structures 18 meters high, 24 meters wide and 24, 48 or 96 meters long. Each rides 9 meters above the water surface on hydraulic legs mounted to submerged tubes of a SWATH (Small Water-plane Area Twin Hull). Dynamic positioning by multi-directional pumps and vertical, real-time corrections for wave movements by hydraulic legs stabilize the system.

Increasing Environmental Potential

Since usable land space for many countries is decreasing while industrial capacity is increasing, water-based industry may be a natural direction for evolution. The Mobile Offshore Industry concept holds considerable potential, since the world's bodies of water cover two-thirds of the earth's surface. If factories and production facilities were to move onto the water, away from shore, more land would become available for habitation and for the functions which contribute directly to the quality of living.

In addition to providing sources of energy to run the machines, oceans and other large interconnected bodies of water offer a free, high-capacity, omnidirectional transportation medium. In a Mobile Offshore Industry installation, large Distribution Modules located throughout the configuration allow ships to dock easily, promoting quick turnover of manufacturing inventories. As an alternative to orienting operations to the location of the factory, the system also has the capability of moving through the world's waterways to orient the factory to the best location for operations—determining location by economic, political or environmental advantages. Widths of all structures in the modular system are 24 meters, a size chosen to assure passage through all major man-made canals.

The SWATH Concept

SWATH means Small Water-plane Area Twin Hull. This concept, which is employed in all elements of the Mobile Offshore Industry system, helps to increase stability in a water-borne structure. The SWATH principle concentrates buoyancy for a vessel in two submerged "pontoons" well below the water surface. Rising from the pontoons are thin stilts, which support the body of the vessel totally above the water. The stilts are the only elements that pierce the water plane. Having virtually no area of the vessel to interact with, surface waves play a much reduced role in the vessel's motion.

As adapted for units of the Mobile Offshore Industry system, the SWATH design specifies two submerged hulls, each 6 meters in diameter. These hulls support the working structure 9 meters above water through cylindrical hydraulic legs, which withstand the forces of the waves at the surface. Vertical corrections for wave movements still encountered at the depth of the hulls are made by the hydraulic legs, which work continuously to stabilize the above-water structure in the horizontal plane. Access to the hulls, where power and propulsion equipment is located, is through the hydraulic legs. Overall trim is adjusted by shifting

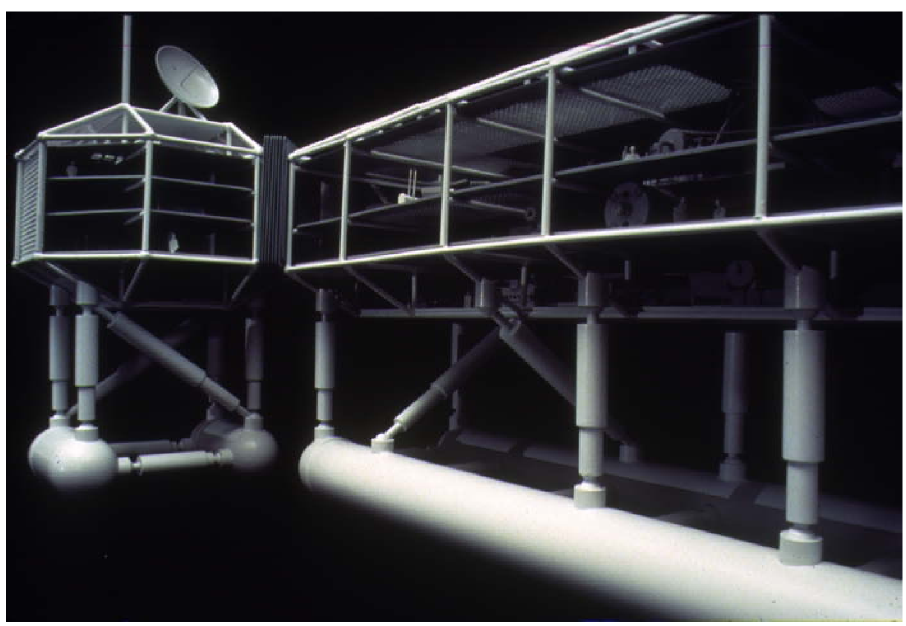

Figure 2 **SWATH Construction**

Floating bodies well below the water surface support modules of the system. Working areas, well above water, are held by the floating bodies with hydraulic legs presenting little resistance to waves.

water and fuel ballast in the hulls; dynamic positioning of units relative to each other is accomplished by multi-directional jet pumps, a part of the each hull's propulsion system.

System Movement

To relocate a Mobile Offshore Industry installation to another area, Modules are detached and connected end to end to form long trains or caravans under tow. Alternatively, individual Modules, in some cases, are able to relocate independently under the power provided by their individual propulsion systems. On station, this power plant provides power and utilities for operations, as well as power for maintaining station.

Interior Construction

Elements of the system are all similarly constructed. Intentionally modular, they have decks that match up when they are joined together so that they can be assembled in configurations appropriate to a variety of jobs.

At the bottom of each Module is a 3.5 meter high space that accepts the hydraulic legs and houses the machinery for controlling their motion. The remaining space on this deck is shared between storage functions and the ports and equipment used for handling and operating utility transporters (small work boats). In form, the bottom surface is faceted to deflect winds and exceptionally high waves (over 9 meters).

The middle deck of each Module has space 10 meters high; however, supplementary decks can be added at 3 meter intervals within this space. Flooring for these decks is .25 meters thick, with an additional .25 meter space for the support structure in which the flooring is set. Supplementary decks are generally used in Modules such as Habitation Modules; in contrast, a Distribution Module would be more likely to retain a maximal open space in order to allow the movement of equipment such as large cranes through the space.

The top deck of a Module is identical to the bottom in size and shape, but is inverted to present the faceted, relatively streamlined form to the weather. The entire overhead covering surface, however, may be optionally excluded. Without the overhead surface, the upper deck becomes a large, exposed flat surface which, in the case of a 24 meter by 24 meter Module, is an ideal size for a helicopter pad.

The height of a Module is 18 meters overall. If sections of the middle deck are eliminated, the maximum interior height can be increased to 13.5 meters, a sufficient height to accommodate almost all major machinery.

Module-to-Module Connections

Doors

Two types of doors—tamboured or hinged—are available to connect Modules depending on the purpose the connection serves. Tamboured doors are located at 4, 6, and 8 places, respectively, on the 24 x 24, 24 x 48, and 24 x 96 meter Modules. When Modules are joined directly or joined with Space Frame Transfers, the doors are opened to allow passage between the areas.

For Special Processing Modules that may conduct direct Module-to-ship transfer of materials (avoiding an intermediate transfer to a Distribution Module) the Tamboured doors are replaced with special hinged doors that fold open from the side of the Module. The open doors are supported by a hydraulic arm on each side to form structural platforms for the movement of materials and people between ship and Processing Module. When not in use, the doors are secured by the hydraulic arms.

Module Connection Mechanisms and Protection

The physical connection of Modules is completed by the joining of 4 shock absorbers. At each connection point, a male and female connector extend 1.5 meters from each Module. When two Modules are connected, one-half meter of each of these connectors join together, creating a "buffer" gap of 2 meters between the two Modules. The shock absorbers reduce wear on the Modules by preventing Modules from coming into direct contact with each other except where the manner of contact can be controlled. To permit transfer between Modules, a flexible, rubberized flooring is installed. This flooring is split at the middle of the connection space, and a disc is inserted between the two pieces. The disc compensates for rotational movement between the Modules, while the flexible flooring adjusts for independent vertical movements.

Finally to protect the connection from the elements, a bellows made of non-corrodible, rubberized material is placed over the door framework. The flexibility of this material functions much like the flooring to allow Module movement without damaging the covering.

Space Frame Transfer

If an arrangement of Modules requires space between groupings, a Space Frame Transfer is used. This is literally a structural "space frame" with a deck and an open structural framework that can be left open or covered with a weather skin depending on what will be transferred through it. For example, a Space Frame Transfer intended for the movement of people between Modules would be covered for their protection from rough weather; a Space Frame Transfer to hold conveyors for mined materials would not be covered. A Space Frame can connect Modules by any of the door ports that are available on the eight sides of a Module, permitting the same flexibility possible for direct Module-to-Module connections.

Space Frames are 11 meters high by 10 meters wide and are not configured with supplementary decks because large equipment may have to be moved through them. If a Space Frame Transfer must span a long distance, twin SWATH pontoons are interposed at 48 meter intervals to provide extra support along the way.

Internal Transport

Transport of materials and goods within Modules is supplemented with a system of water conveyors that move Transpac (transportation package) containers over a moving water path. Small water jets located at intervals along these "canal" conveyors push the water and Transpacs at a constant pace. Fins on the Transpacs and rollers in the upper portion of the canals (to bear the weight of heavily loaded Transpacs) maintain the flow. When Transpacs must be moved to another level of a facility, they are moved by an exchange conveyor which pivots down from the overhead to pick up individual units. Slots in the conveyor engage the Transpac fins, to prevent slippage, and allow excess water to drain back into the canal conveyer below.

Flowchart Configuration
Combining functional Modules to perform a particular process allows the flow pattern of the process to be duplicated directly in the physical layout of the Modules. The direct realization of the flowchart for a process in physical plant arrangement is a unique feature of manufacturing at sea.

As an example, an automotive assembly line takes in raw materials or piece parts at the beginning of the line, performs work on them along the line, and produces a finished product at the end of the line. In a manufacturing installation of the Mobile Offshore Industry system, the Modules for such a process may be arranged to take in shipments at one end, store the material until needed, perform the process in the middle Modules, and finally distribute the products at the other end. Such a configuration provides an orderly flow of materials and products—in other words, a structured organization of processes. Moreover, as new technologies are developed and tested, functional Modules can be readily reconfigured or augmented with new Modules equipped to accommodate the changes necessary to remain efficient.

Module Sizes
Modules are available in three sizes depending on what function must be served. The sizes are: (a) 24 meters wide by 24 meters long, (b) 24 meters wide by 48 meters long, and (c) 24 meters wide by 96 meters long. Height (exclusive of water surface clearance) is 14.5 meters or 18 meters, depending on whether the top deck is covered. To assure passage through all of the world's waterways, including man-made canals, the 24 meter maximum width must be no greater than 24 meters. Sizes are chosen to maintain modularity.

One large Module occupies the area of two medium Modules or four small Modules. The size progression ensures that Modules can be arranged so that an optimal variety of connections can be obtained.

Types of Modules
Since each Module performs a specific function or set of functions, Modules in combination can be configured to undertake processes of nearly any complexity. Some Modules, such as those for Waste Management or Distribution, are almost always necessary and are considered "standard" for every system. Others are highly specialized—Materials Processing and Manufacturing Modules are examples—and occur only in systems configured for a specific process. In addition, some processes may be more economically performed in conjunction with other activities, or a symbiosis of processes may help to attain higher levels of efficiency overall for a system.

Standard Modules. The following section describes some of the standard Modules and functional Modules used in conjunction with a specific process.

Communication Module. Communication Modules are an integral part of a system configured to undertake any form of manufacturing or processing. To begin assembly of a system at sea, a Communication Module must be the first to arrive on location; its Communication Center has the communication and control capacity to oversee the functioning of all other Modules. During system assembly, the Communication Center is responsible for marshalling the other components as they arrive on site as well as organizing and directing the assembly process. Under normal operations, the analysis of data gathered to detect and correct system-wide problems takes place in the Center, and general report information as well as specific findings from, for example, Exploration and

Survey Modules are sent from the Center to on-shore stations. The direction and control of incoming and outgoing ships and aircraft is performed by the Center, and whenever the overall safety of the system is threatened, such as during major storms, the Center assumes responsibility for overall stabilization of the system and system-wide tactical maneuvering.

Figure 3 **Communication Module**
Communication Modules are compact structures designed for command and control functions.

Survey Module. Medium sized Modules are used for such surveying tasks as locating subsea oil fields and mapping areas with potentially economic concentrations of minerals.

Door ports on the sides of the Modules allow seismic streamers and other surveying and sampling tools to be lowered to operational depths or to the sea floor. For some modes of operation, such as surveying and exploration, operations may continue while the Module is in motion, and, in fact, Survey Modules are especially active during periods when a system is moving to a new location. When operating independently, they are frequently accompanied by a Communication Module; in other configurations they are located within sight of a Communication Module for direct data transmissions at high frequencies.

Distribution Module. Distribution Modules are found throughout almost any system configuration in either of two forms: a 24 x 24 meter Module specialized for helicopter (and VTOL) handling, or a 24 x 96 meter Module for ship docking. Distribution Modules for use with aircraft are outfitted without an upper deck covering to provide a large flat surface for landing. They are marked with a large blue "H" to distinguish them from similarly shaped Emergency Modules. The large Distribution Module for ship-to-Module and Module-to-ship transfer is built with a special structure on the top: a long, centrally-located, open hatch through which cargo is transferred. Along the sides of the open hatch, running the length of the Module, are two rails for traveling cranes. The cranes are used to load and unload ships in normal operations, but they may be employed for support of assembly operations and can be important in emergency situations.

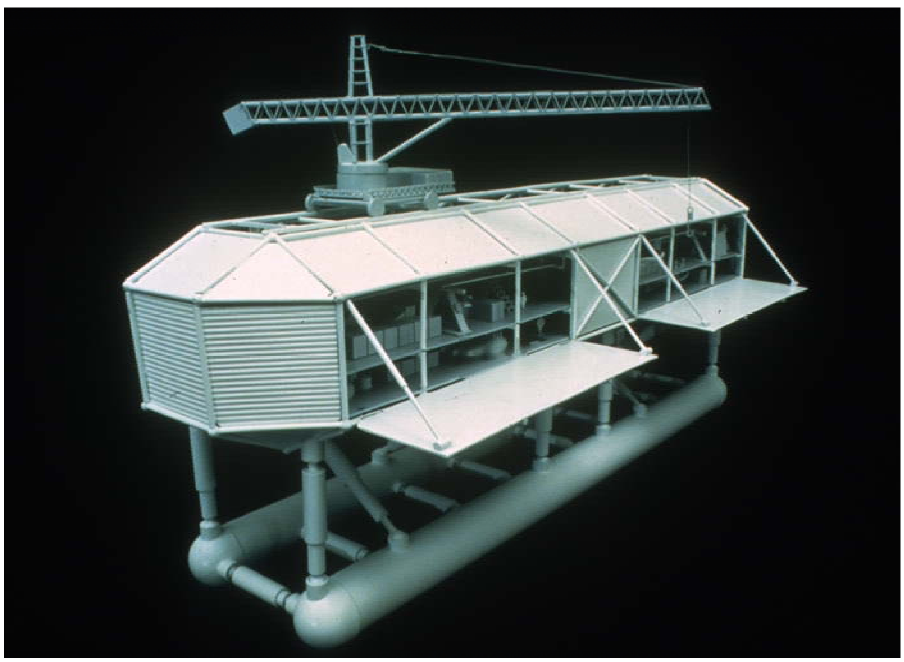

Figure 3 ***Medium Module***

Modules of the system are typically large working spaces, up to 24 meters by 96 meters, supported by SWATH technology and outfitted as necessary for their working roles.

Emergency Module. Minor medical problems can be treated almost anywhere in the system. The Emergency Module exists for serious medical problems and disaster conditions. Helicopters and VTOL aircraft can land on its flat upper deck, and it is clearly distinguished from the similarly shaped Distribution Module by a large red "E" marking. In case of a disaster, this Module must be able to accommodate large numbers of people (possibly the entire crew of the installation). In this mode it exists to assure life protection; therefore, it must be able to operate detached from the system and be able to maneuver independently

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to save lives, maintain survivors and return them to safety. Since this Module has its primary mission associated with the most hostile of conditions, it is outfitted for severe service and has greater capacities for self help, special maneuvering and life support than other Modules. In a system configuration, it is located carefully to be as clear as possible of potentially hazardous areas, ensuring that it will have a good chance of surviving an accident.

Habitation Module. Among the standard Modules are those used for habitation. The smallest size Modules are ideal for living quarters and, as Habitation Modules, are specially outfitted for the system crew. To allow rapid movement of crew members to and from their workstations, Habitation Modules are strategically located throughout the system. Crew members, consequently, can be assigned to quarters that are relatively close to the Module in which they work. To assure that "quality of life" is maintained in the system, recreational facilities and equipment are installed in Modules directly attached to the Habitation Modules. Upper decks and side walls of Habitation Modules are constructed with window ports equipped with adjustable blinds for sun control—to add an element of spaciousness to the quarters.

Specialized Modules and Specific Processes

Vehicle Manufacturing

This form of manufacturing exemplifies processes useful for developing countries. A Mobile Offshore Industry Manufacturing System can teach manufacturing technology and raise worker skills while providing needed transportation products in the form of light trucks, or construction equipment such as bulldozers, trucks and road building vehicles. Raising the level of industrial skills within a country is one of the most important objectives for development. When significant progress has been made, the system can be moved to another location to begin another round of local education and training. Permanent factories can economically follow with a work force available to staff them. Since urban centers in most developing countries are located on large bodies of water accessible from the sea, there is considerable opportunity for manufacturing of this kind.

A vehicle manufacturing system is also an excellent choice to demonstrate the use of flowchart Module arrangement. A large Distribution Module is located at one end of the configuration where raw materials and piece part shipments are received. The main construction center is comprised of two large Production Modules connected side-by-side where their door ports can be opened to create a large open deck area for component construction and assembly. At the ends of the main production area are one or two more Distribution Modules to temporarily store finished goods and speed their delivery (minimizing inventory problems). Also at the end of the Production Modules are Waste Management Modules to separate and compact waste that can be recovered, and to chemically treat and incinerate nonrecoverable toxic waste.

Offshore Mining

To provide enough space for equipment such as conveyors and dredges, at least two large Modules must be combined for mining of offshore minerals. These Modules can be separated and a grid flooring placed between them to provide a large, open work space for deployment of equipment that must be lowered into the water. Large winches are deck mounted for this task. The Module interiors also contain equipment for the preliminary processing of dredged material and extensive storage facilities for holding the material until it can be shipped.

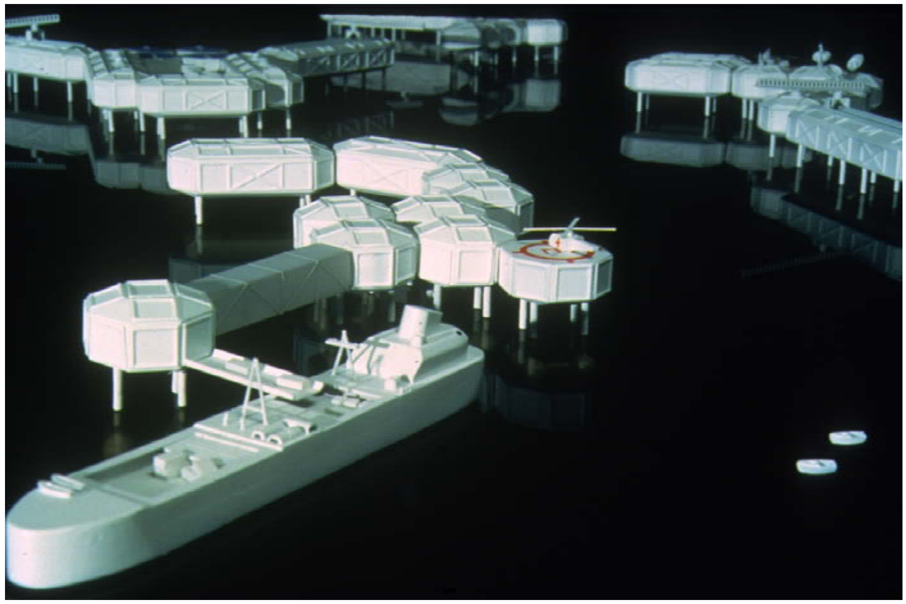

Figure 4 **Truck Assembly Plant**
Configured for truck assembly, a Mobile Offshore Industry installation exemplifies how industrial know-how can be transferred to developing countries without extensive land construction.

Onshore Mining

Remote areas that can only be reached by water demonstrate the value of a Mobile Offshore Industry onshore mining system. Systems can be configured to bring mining operations within close proximity to shore. Combined with land-based equipment brought in by sea, an installation can perform mining operations along coastal areas and within reasonable distances from large river systems. Materials Processing Modules are set up in a pattern so that raw materials come in from land, and waste and bulk processed materials leave by sea. To reach a deposit to be mined, two large Modules are positioned at the shore end of the system with their hinged doors opened toward the land. Over the large platform created by the lowered doors, material handling conveyors are deployed to shore and onto the deposit. Preliminary separation is performed by the Processing Modules and unusable material is passed to the waste units at either end of the system for return to a dump site on location.

Extraction

In general, extraction is the process of separating elements or compounds from water by physical or chemical means. Frequently this involves preliminary concentration by evaporation. The upper decks of small Modules without deck coverings are configured as extraction ponds for this purpose (larger Modules can be similarly configured for larger-scale operations). Further physical or chemical refinement takes place on lower decks where reverse osmosis techniques,

electrolytic decomposition or other processes may be employed depending on the extraction objectives. A major use for Extraction Modules is the production of fresh water, where the byproduct, brine, is the source of economically valuable elements and chemical compounds.

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