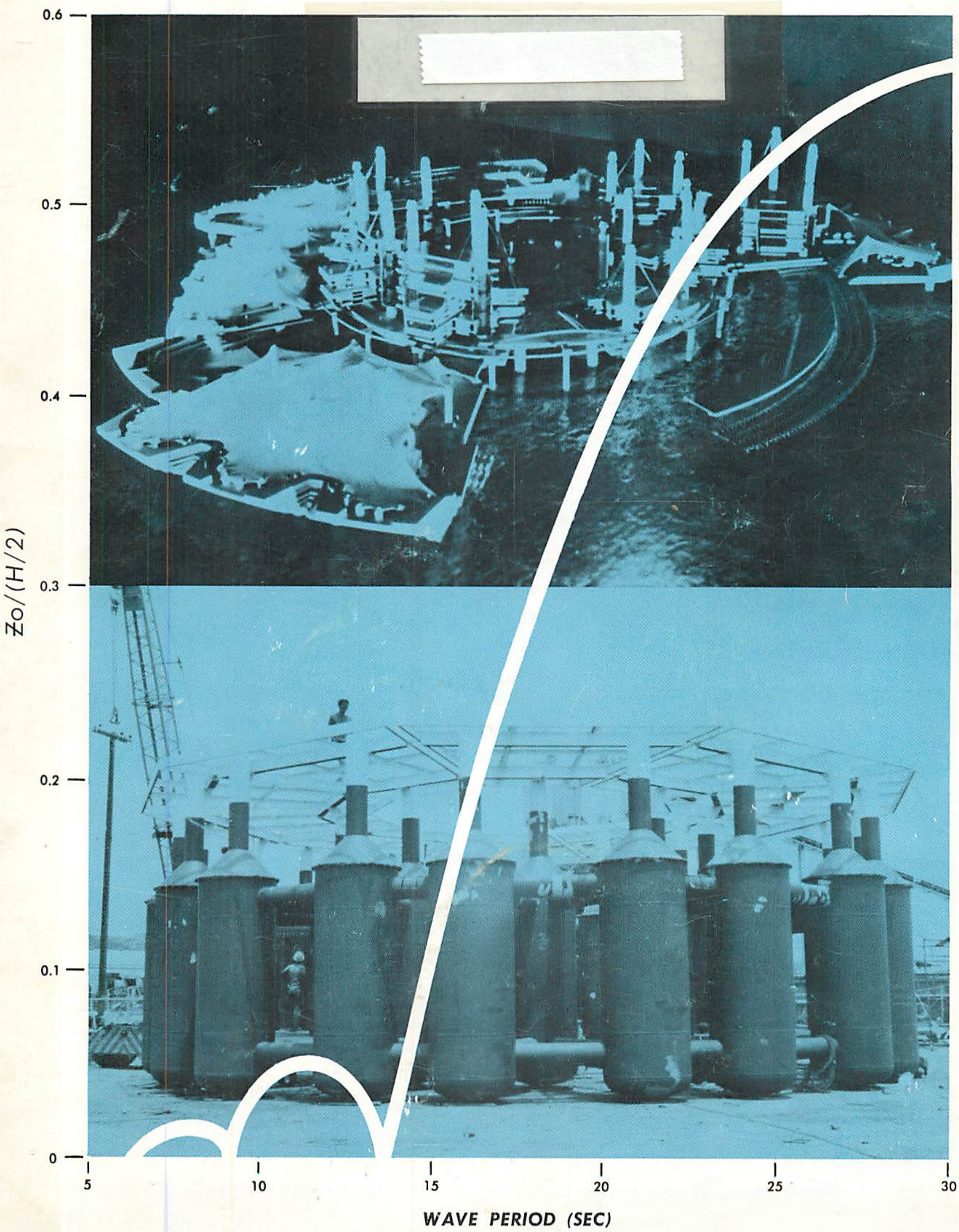
HAWAII'S FLOATING CITY

DEVELOPMENT PROGRAM

FIRST ANNUAL REPORT - FISCAL YEAR 1972



FIRST ANNUAL REPORT

HAWAII'S FLOATING CITY DEVELOPMENT PROGRAM

FISCAL YEAR 1972

Published jointly by the University of Hawaii
and the Oceanic Institute

Principal Investigator - John P. Craven, University of Hawaii
Program Manager - Joe A. Hanson, Oceanic Institute

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Cover photos: Chuck Peterson and Steven Ribakoff

Preface

The concept of total systems design for major urban needs of our society is as yet new and untried. Whereas major defense and space systems have been successfully designed, developed and constructed; the urban society has had only partial, piecemeal and uncoordinated development with a "fruit and nut cake" mixture of private and public capital. The result is an inefficient air transport system, an absurd automotive and public transportation system and cities which are environmental, economic and social disasters.

It may seem presumptuous that in the midst of a society of great industrial wealth and a gigantic federal research and development structure, a small under funded and remote University-private research Foundation team should step forward with a bold concept for total design of a marine based urban society. However, the individuals who constitute the senior members of this team represent a combination of unique experiences. They have been involved in the creation and development of major military systems and in the planning processes that have produced such successful systems (and a few unsuccessful ones); and they have also had experience at the centers of chaos of urban planning and design. From this experience, there is a firm conviction that this program and this concept could not have been initiated by the normal development processes of our society. Indeed, we conclude that, as presently constituted, our society forbids a whole system approach to the design of urban systems.

It is, however, our hope that this small but unique group has produced a seminal program--generated "far from the madding crowd"--which, flourishing as a concept to introduce total urban system planning in an evolutionary and organic manner, will grow into real urban complexes of major benefit to man and his environment.

John P. Craven

TABLE OF CONTENTS

A PROGRAM OVERVIEW

The introduction of modern technology has produced great demographic changes in the world society. Almost overnight populations have deserted the agricultural areas of the world, have congregated in the cities and migrated to the coastal zone. This shift has been coupled with rapid population increases and unplanned explosion in the use of natural resources. The result has been at the least an illusion of exponential growth, a Malthusian crisis and a threat to the continued availability of natural resources. Most thoughtful analysts agree that this pattern must be changed.

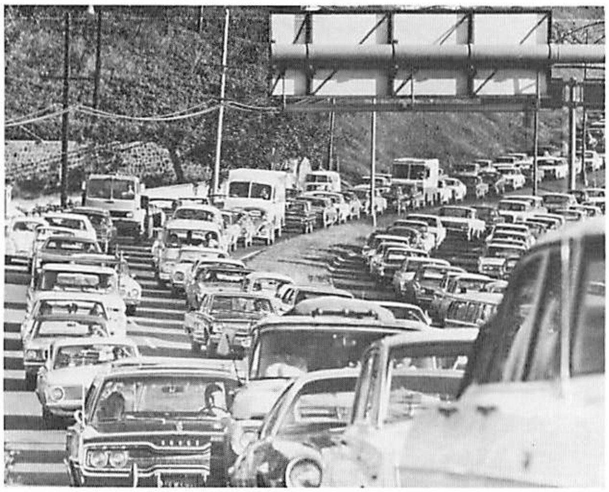
Yet, individual human societies, though in themselves astonishingly complex, are only parts of the complexity of the world social system. Systems of high complexity change slowly; and so we cannot expect the present rates of population increase to become asymptotic overnight, even though we know they must diminish and then halt very soon. So we need time: time to understand our social systems and time to re-direct their development toward an eventual equilibrium with the global ecosystem.

The land that has supported our societies in the past is less than one third of the globe potentially available to us. The other two thirds are in the world's oceans. Contrary to the public myth, the oceans have in fact a great potential for solving environmental problems of modern industrial technology as well as having the scale ratios for efficient economies. Inevitably we must turn to the oceans for space and resources which might provide our scientists, business leaders, and government officials the time to bring our societies into equilibrium with their environment.

The resources of the oceans lie beneath the surface and sometimes beyond the bottom itself. Yet, man is a breather of air and cannot for long remain beneath the surface without special equipment. And this surface is frequently turbulent. So we must conclude that a first giant stride into the oceans lies in the development of large stable floating platforms, divorced from the turbulence of the air-sea interface, extending into the air and the sunlight in one direction and into the resource-laden depths in the other. Such platforms potentially seem capable of supporting particular industrial endeavors, applied science programs, and even whole cities.

Cities in the Sea

The dawn of modern civilization was characterized, if not initiated, by human predilection for the formation of cities. It seems safe to assume that the trend will continue. The size today's cities may attain appears limited only by space and technology, and the complexity they develop without plan exceeds man's individual and collective comprehension. We have been unable to moderate, much less halt, either their growth or the environmental pollution and logistic impaction it brings. And, we seem incapable of dealing effectively with inevitable urban decay and its sociological companions: crime, unemployment, subculture conflict, and other crucial indications of general cultural breakdown.



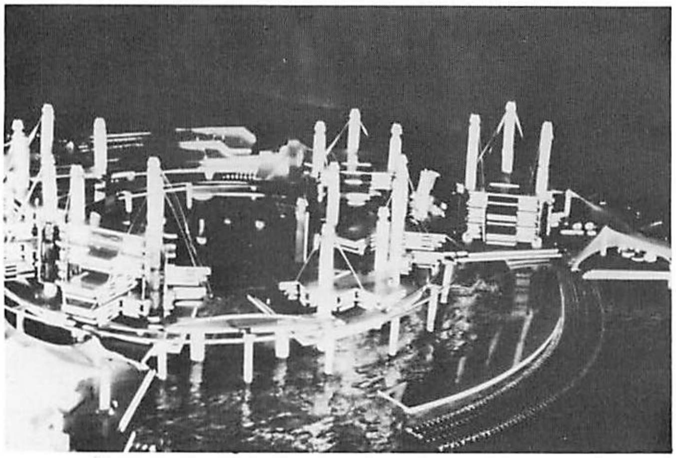
We are not entirely sure how our major urban problems got this way, much less what to do about them. We do recognize, though, that these problems are interrelated and that the unplanned and unlimited growth of our modern urban complexes threatens the life of the land and the waters, as well as the life of these complexes themselves. Our historical "laissez faire" approach to urban development, coupled with today's and tomorrow's technology, has been likened to a cancer spreading destructively until it kills the host and itself.

Toward a solution, architects such as Soleri and Doxiadis have proposed vastly increased planning and control which, in fact, constitute "systems engineering." They and others recognize also the double bind created by the need to preserve the natural world through urban size limits on the one hand, and the upper urban density limits imposed by two-dimensionality on the other.

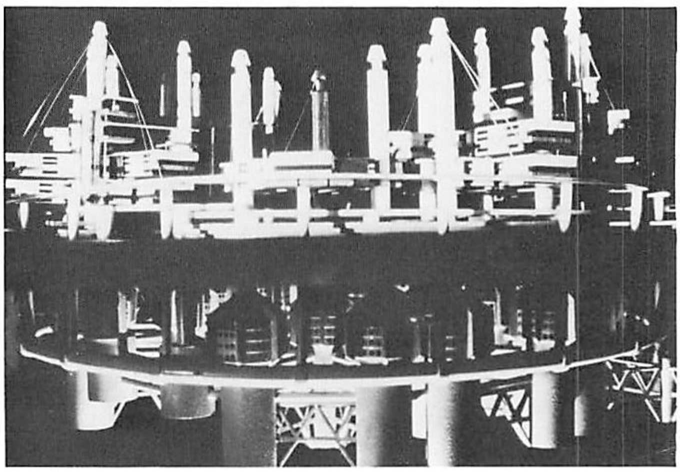
And so we find three-dimensional urban systems in conceptual design: systems in which personal and logistical transportation would form a semi-automatic, pollution-free internal lattice work; systems in which the automobile and its attendant problems have been eradicated; systems which purport to restore the vitally important sense of community to their inhabitants, through a delicate balancing of closeness, openness, cleanliness, quiet, and aesthetically pleasant surroundings.

Unlike single purpose systems such as the moon program, solutions to our urban problems require the simultaneous achievement of a multiplicity of goals, many of which conflict with others. It may be that systems design has not yet developed to the point where it can grapple with urban systems. Nevertheless, we feel we must try to plan and engineer our urban complexes as whole systems. The only alternative we can perceive is more of that which we already know does not work. If our systems approaches are not yet adequate, we must develop them further. If, by chance, they are adequate, we must demonstrate it.

So we conceive of engineered three-dimensional city-systems as a first step toward urban sanity. We recognize the inherent difficulty involved in achieving true urban three-dimensionality on land. And we see that structural complexes tied to the land are not easily removable either. So they must inevitably be overtaken by technology and thereby become obsolete. But if we look to the seas, we find that the technology for building three-dimensional, floating urban complexes is well advanced. Furthermore, we recognize that the fluidity of the oceans permits building an evolutionary capability into our cities through modularity and mobility. We recognize that marine transport is still the most efficient, and therefore the least expensive form devised. So we see that the oceans offer us an opportunity to build our cities, or even move them, almost anywhere we like.



The Hawaiian Islands and Japan are two of the largest, technologically advanced, marine-oriented societies. They both feel the stresses of population pressures more acutely than societies enjoying more land area. They both watch their agricultural foundations crumble as their urban cancers spread. Therefore, they both feel intensely their increasing dependency on the outside world for food and raw materials. It does not seem strange then that the idea of floating communities should emerge in these two places before it emerges on a continent; nor that the scientific and technical talent to begin floating urban systems experimentation should flower first in these two societies.

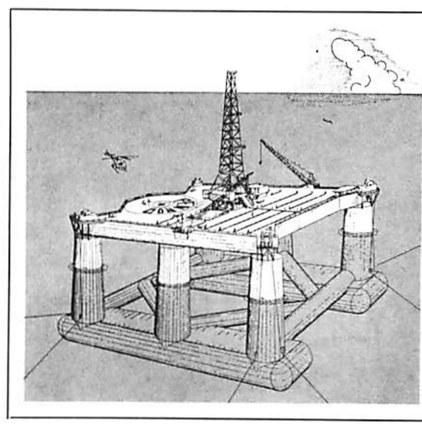


Therefore, while we maintain high interest in other applications of very large stable ocean platforms, cities in the sea, achieved through international cooperation, stand as an ultimate goal of our efforts.

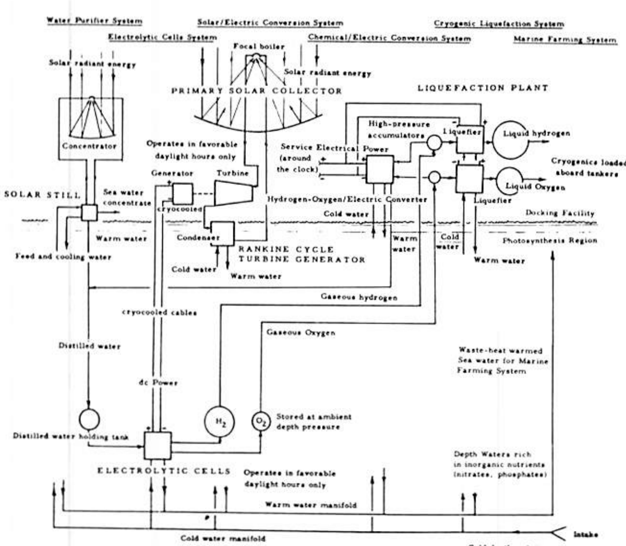
Other Uses of Large, Stable, Open Ocean Platforms

But sea-based urban complexes, while within the reach of today's technology through systems engineering and management, will very likely be preceded by more modest manifestations of the stable floating platform concept.

All stable platforms of which we speak are members of a class of floating structures termed "semi-submersibles." Such platforms have the majority of their mass and buoyancy placed well below the turbulence of the air-sea interface zone. Only thin columns penetrate this zone; so the energy contained in its turbulence produces little effect on the whole structure. The oil industry of the United States has been a leader in the development of these structures; and, since semi-submersibles have proved themselves invaluable for the extraction of oil in the deep ocean environment, we may expect to see developments for this purpose continue and increase over the next few decades.

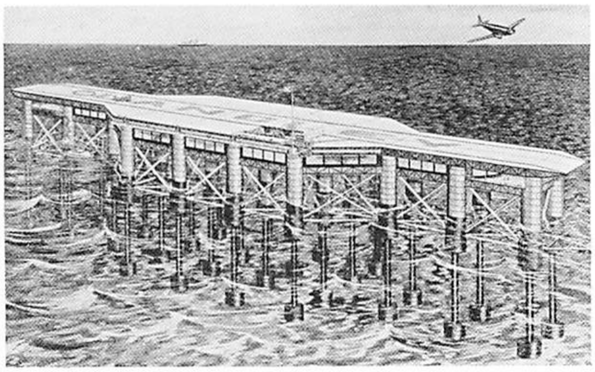


Recently, the nation's power industries have begun experiencing the inevitable squeeze engendered by burgeoning populations demanding a comfortable and aesthetically pleasing environment in which to live. On the one hand more and more power is demanded. On the other, less and less environmental degradation is tolerated. So the power industries, too, begin looking into the oceans as potential power generation sites. In the near future, these sites will most probably be based on fossil fuels and nuclear energy sources. But we may hope for, and must work toward, eventual cleaner and longer lasting energy sources too. New sources that appear promising at present include wave energy, geothermal energy, and solar energy--all essentially inexhaustable and environmentally innocuous.



Helios Poseidon - Clean energy from sun and sea?

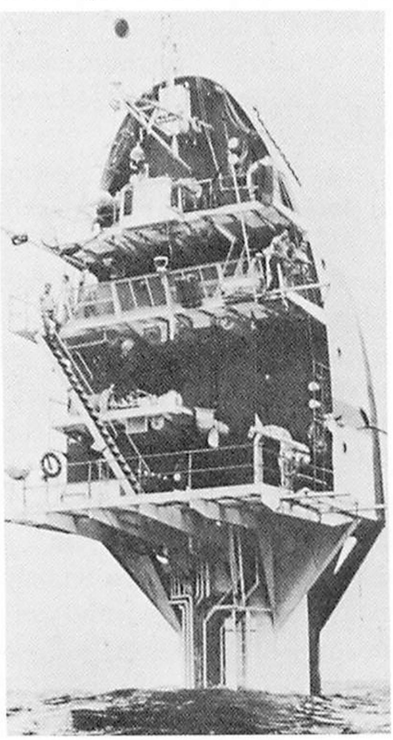
We will probably continue to rely on high speed aircraft for mass transportation even though we may soon have to abate or discontinue its reliance on fossil fuels for power. Already the ground support requirements of our large, high speed aircraft have engendered massive urban problems. Can these be solved by basing the "ground" facilities at sea? Many prominent technologists are attracted to the possibility and several possible designs have been proposed by both civilian and government agencies. Clearly, large semi-submersible platforms must come into consideration for this application also.



E.R. Armstrong's Seadrome

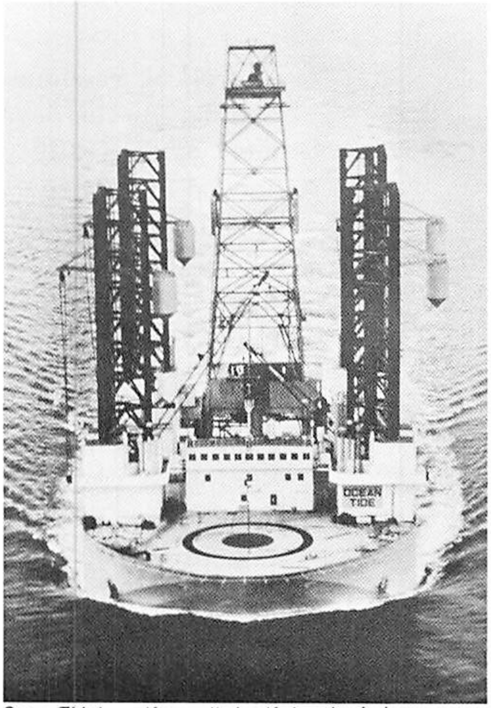
Early Emergence of the Floating City Concept

Gregory Bateson, one of our nation's revered scientist/philosophers and long a resident of Hawaii, is fond of asking the rhetorical question, "Who owns an idea?" It seems that nowhere is non-individual ownership of a complete and coherent idea better exemplified than in the social and scientific evolution of the floating city concept.



FLIP, on station

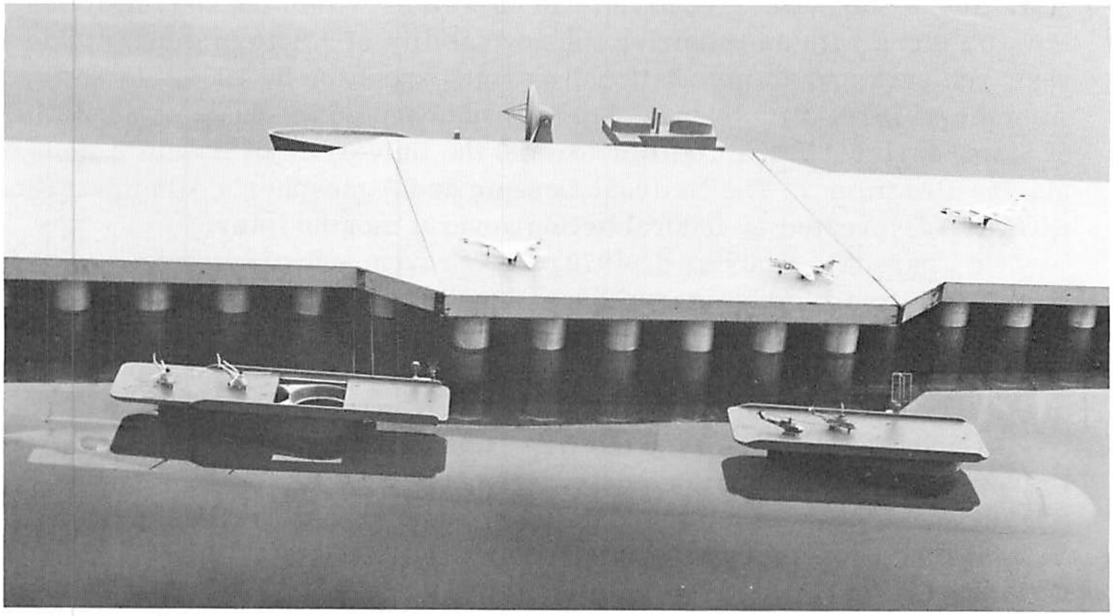
As early as 1922 E. R. Armstrong advanced the idea of a "Seadrome". In the mid-1960's marine scientists were experimenting successfully with large "spar buoys" such as FLIP and SPAR as an approach to needed stability in deep heavy seas. Even earlier the visionary architect Paolo Soleri identified problems being created by exploding urban sprawl; and so advanced conceptual designs for high density, three-dimensional land based urban complexes which would preserve the major share of a nation's agricultural and conservation areas. Others began advancing various ideas for off-shore airports as the jet age began to make its side effects felt in the nation's cities. In the mid-1950's the military establishment and the petroleum industry already



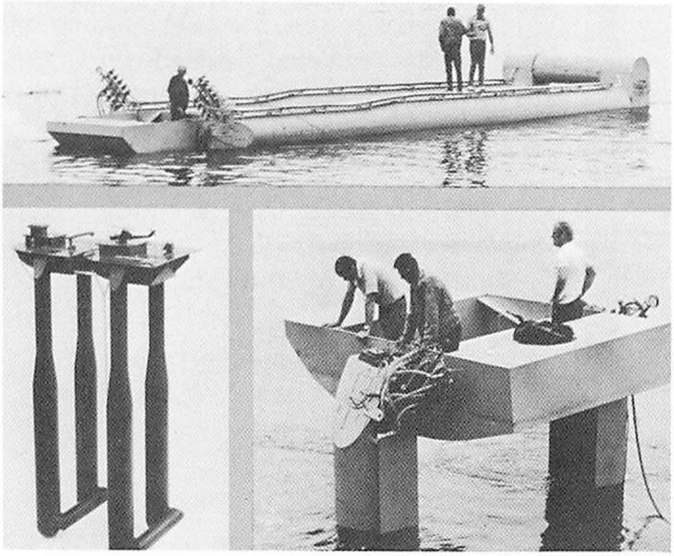
Ocean Tide is a self-propelled, self-elevating jack-up.

had demonstrated the feasibility of off-shore man-made islands with "Texas Towers" and oil drilling rigs that could be mounted on the ocean bottom in tens of fathoms of water. Then, in the early 1960's, the petroleum industry stepped out into deep water with its floating semi-submersible platforms; and this was followed a few years later by investigations of spar buoy clusters by the Naval Undersea Center and Scripps Institution of Oceanography.

In January of 1969, the United States' Commission on Marine Science, Engineering and Resources published "Our Nation and the Sea-- A Plan for National Action;" a report that must be recognized as a prime catalyst for the concerted national marine program now emerging. One of that report's prime recommendations was for the centralization of responsibility for national marine and atmospheric science and technology in the "National Oceanic and Atmospheric Agency." However, woven throughout "Our Nation and the Sea" are implicit and explicit recommendations for state-centered responsibilities and actions



Naval Undersea Center's Mobile Ocean Basing System



Scale model of Scripps' new 4-column FLIP

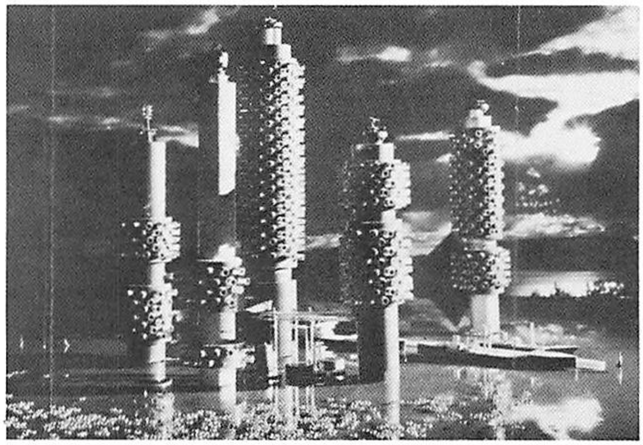
as well as recommendations for the development of critically needed off-shore technology.

Hawaii was the first state to respond in kind to the national commission's report. Governor John Burns' Task Force on Oceanography established a study group consisting of approximately one hundred volunteer professionals in ocean science and technology led by William S. Beller on loan from the U.S. Department of the Interior. In September of 1969 this study group produced "Hawaii and the Sea--A Plan for State Action."

"Hawaii and the Sea" contained twenty-two specific action recommendations for understanding, utilizing and preserving the state's marine environment and its resources. More than one-third included recognition of the need for centralization of authority for the state's diverse marine activities at the State Executive level as well as within the University of Hawaii, along with emphasizing the advisability of a State oceanographic research park and an international marine exposition by 1980. By late summer of 1970, Dr. John P. Craven had accepted the dual responsibilities of State Marine Affairs Coordinator and the University of Hawaii's Dean of Marine Programs. The National Oceanic and Atmospheric Administration (NOAA) was created by federal action several months later.

On Thursday, October 6, 1970, Dr. Craven, substituting for Taylor A. Pryor, addressed a dinner meeting of the American Institute of Architects. On the following morning the Honolulu Advertiser carried a front page headline, "A Floating City off Oahu?" A week later an editorial in the Honolulu Star Bulletin challenged Dr. Craven to substantiate the dream.

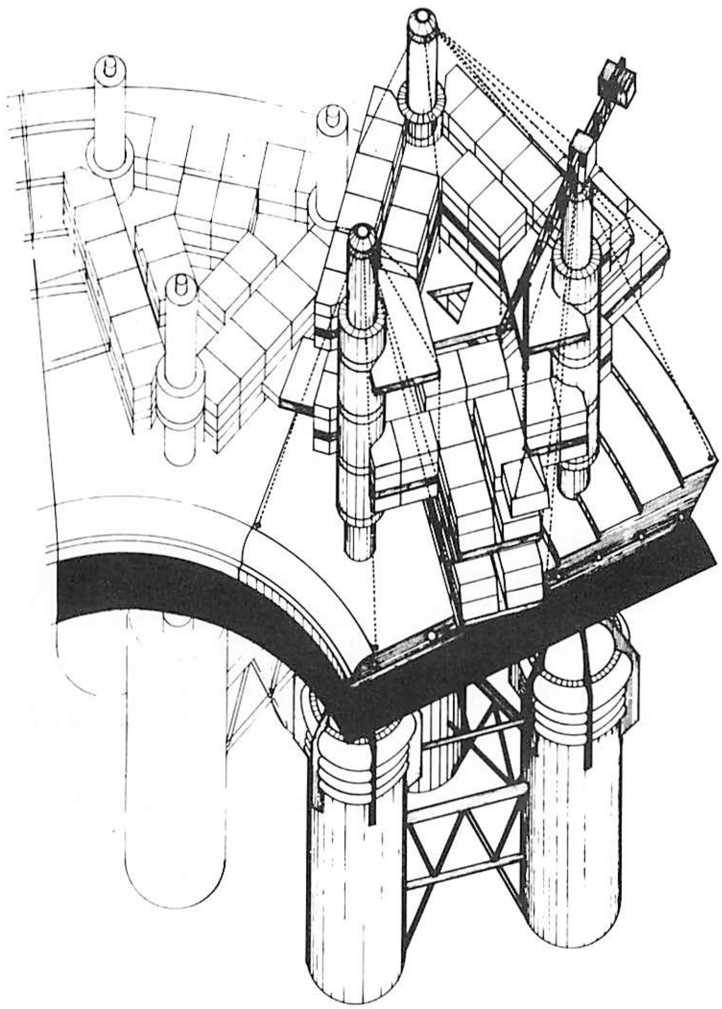
At about this same time, the Department of Architecture of the University of Hawaii completed arrangements with Professor Kiyonori Kikutaki, a leading proponent of advanced marine communities, to come to the University as a visiting professor during the Spring 1971 semester. Early in 1971 the Office of the Marine Affairs Coordinator issued Task Order #2, allotting $25,000 to the Department of Architecture to conduct studies of, and accomplish preliminary design for, a stable floating marine research park and also to give consideration to the employment of such a structure as an international marine exposition. This funding was later augmented by Task Order #8 for an additional $25,000 to continue the work.


Residential towers of Kikutaki's marine city.

A number of leaders in oceanic affairs became interested in the project and involved themselves on a regular basis. Weekly meetings were held, and definite areas of responsibility were assigned as follows: Hugh Burgess, Coordinator of Architecture; Dr. Manley St. Denis, Ocean Engineering; Karen Pryor, Coordinator for Social Considerations; George Wilkins, of the Naval Undersea Research and Development Center, Coordinator for Marine Construction; and Dr. John Craven, Marine Systems. This group spearheaded a number of sub-teams. As architectural ideas were developed by students in the Architectural Department of the University, they were checked with ocean engineering and construction teams for feasibility. Other considerations included aesthetics, economics, and environmental quality. A number of computer studies were performed, and a small test model was studied in the water. Funds from the first Task Order took the project through the computer studies, initial engineering studies, the small test model, and half a dozen "semi-final" basic design concepts. The primary result of Phase I was the generation of fifteen design requirements for new cities and the determination that a particular form of the stable platform could meet these requirements.

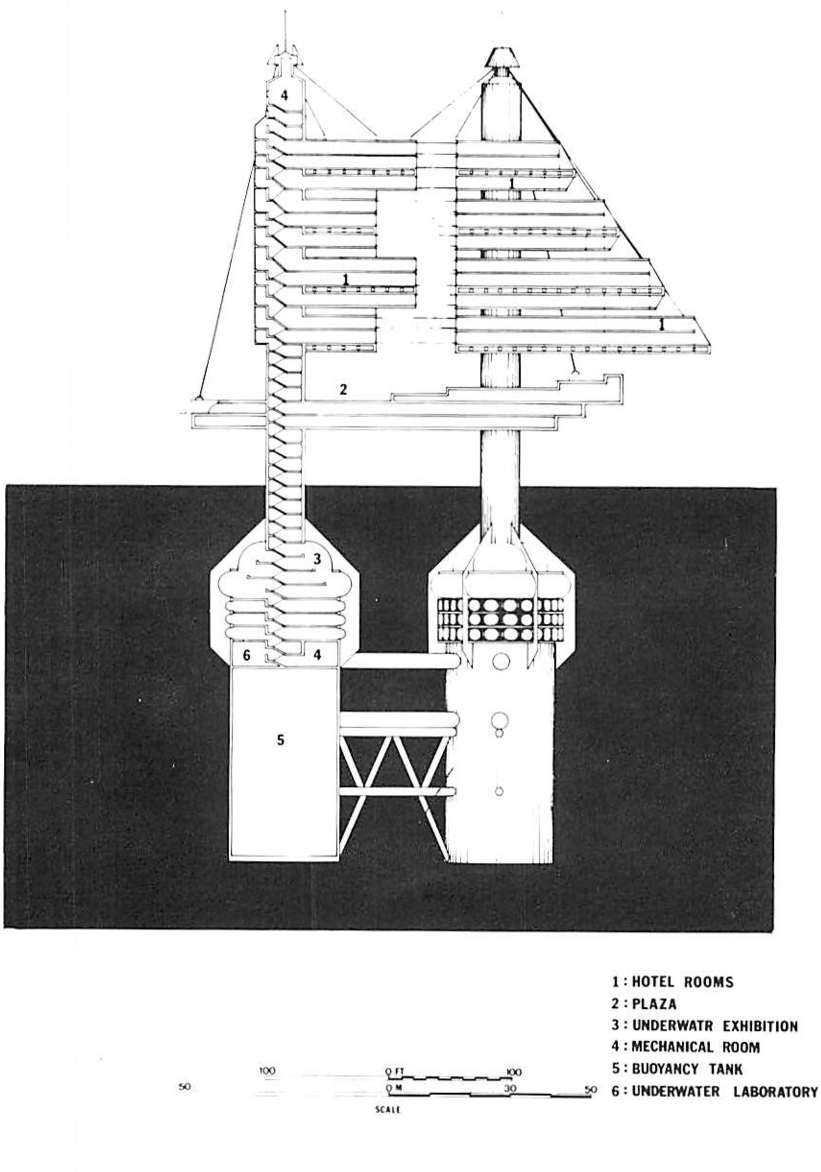
The second Task Order Phase resulted in a single concept and a single model. It is a modular approach with unit modules that can be added or subtracted as requirements change. The modules are scaled to match functional needs (i.e., power module, hotel module, city center, living complex, etc.). The modules themselves are modified pie-wedge shaped units that lend themselves to assembly in circular arcs or full circles and series of concentric rings. Each module matches the three level city concept with a three-tiered upper platform, three relatively small diameter columns which pierce the surface and three large diameter, 250-foot high columns which are fully submerged. The lower columns are to be used for heavy industry and public works functions of the city.

The matching of stable platform concept to urban design attracted interest at the federal level in the early summer of 1971.



Floating City Module Perspective

Floating City Module Side View



PROGRAM ACCOMPLISHMENTS: FISCAL YEAR 1972

Hawaii's Floating City Program graduated from an exploration and planning activity to an applied research program with the initiation of support from the Sea Grant Office of NOAA, U.S. Department of Commerce. This support began in September of 1971 as Sea Grant #2-35243. Its monetary value was modest ($85,000); but its impact on the program's momentum was dramatic. For, with the realization of federal level recognition and support, diverse sectors of the Hawaiian community began to move rapidly toward a unity of interests and goals relating to large stable floating structures. And the technological momentum thus created began to attract broader national and international attention.

It must be recognized that the city in the sea, since it encompasses most or all technical and socio-economic challenges associated with the structures in question, is the primary focus of Hawaii's program. So our long range visions are heavily flavored by this concept. Nonetheless, current practicalities dictate that we focus too on the means; and means in our terms are practical intermediate milestones. These milestones, as we mentioned heretofore, may lie in the gradual movement to sea of components of society such as power generation, transportation terminals, resource extraction, and resource processing; and they may lie too in the creation of demonstration prototypes of three-dimensional urban complexes for international expositions so that they may be experienced and evaluated by people of all nations.

Research

Objectives

The applied engineering research program is a joint effort between the University of Hawaii and the Oceanic Institute, with Dr. John Craven as Principal Investigator and Mr. Joe A. Hanson of the Oceanic Institute as Program Manager. The work is focused on three main objectives:

- To initiate exploration of the engineering design, construction and construction logistics of a floating marine community and exposition proposed for development off the coast of the Island of Oahu in the State of Hawaii.

- To aid in developing a broad base of resident knowledge and skills to be applied to such a development.

- To determine the feasibility of inducing general community understanding of, and support for such a development.

It was decided very early that the most judicious approach to the massive systems engineering problems implicit in this work would lie in restricting the initial scope to an investigation of the fundamental concept developed by the state funded committee, as well as restricting it to the ten-module, core ring of that concept. The work does not treat architectural questions, but focuses on the main platform as a problem in buoyant body dynamics and in static and dynamic loadings.

However, in order to treat even this somewhat restricted problem adequately, the research team determined that an early definition of mission requirements would have to be derived. These requirements were based upon three uses to which the structure would be put on the one hand, and upon the environmental conditions it must withstand in its proposed location three miles off the leeward coast of Oahu on the other. Thus, five avenues of investigation to be followed in the work were defined: (1) systems integration, (2) environmental analysis, (3) theoretical analysis of seakeeping, (4) scale model research, and (5) overall preliminary engineering.

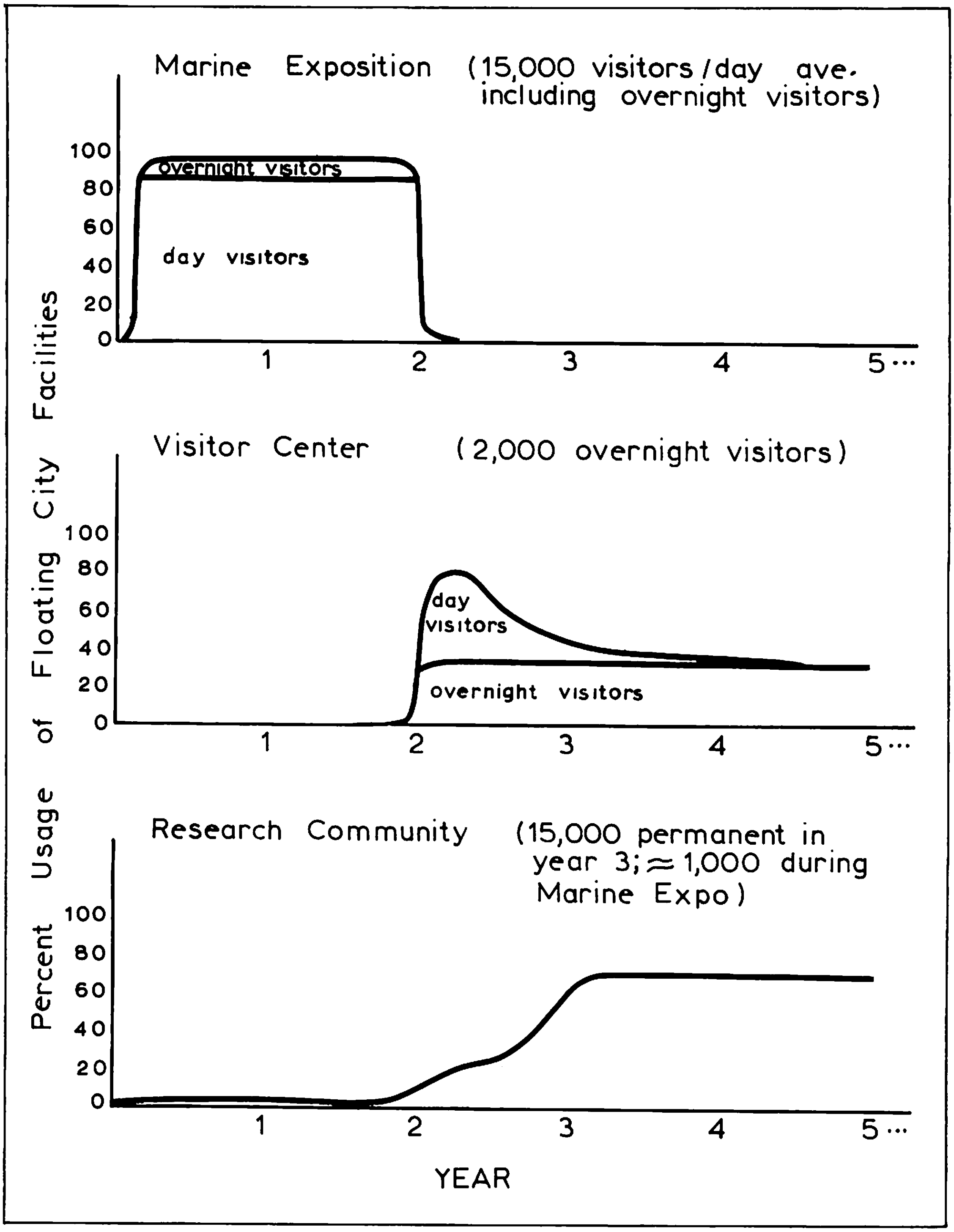
Projected uses of the structure were defined as:

- An International Marine Exposition for a duration of one to two years beginning with the structure's active life, during which it would support a small residential population but would accommodate an average of 15,000 visitors per day with a peak attendance of 40,000 per day.

- A longer term visitor attraction center capable of accommodating a minimum of 2,000 overnight guests, at least 7,500 diurnal visitors and a resident population gradually rising to 15,000 by the third year.

- A floating marine research park and experimental three dimensional urban complex with a residential population of at least 15,000.

These three uses of course are not discrete. Rather they flow into one another as the graphs of comparative population projections for the structure's early years clearly show.



Comparative Population Projections, Floating City Early Years

The Systems Integration Study was supported by these projections, in that they were employed as the bases for determining the characteristics and size requirements of the various systems that would comprise the whole functional complex. During FY 1972, a draft report "Floating City Contained System Requirements and Integration" was prepared by M.A. Lucas and Guy N. Rothwell covering the following subjects in some depth.

1. Environmental Control - including platform stability requirements, ambient noise allowances, and air conditioning requirements.

2. Communications, both internal and external - including telephone, data transmission, command radio, security requirements, broadcast radio and television, public address, postal service, and other printed media such as newspapers.

3. Warehousing and Storage - including such factors as perishable and nonperishable storage, thirty-day survival without resupply requirements, interface with the transportation system, and automated distribution of consumer goods.

4. Water Supply - including cost/benefit analysis of desalination versus transport from land, the supply and distribution system itself and usage divisions between saline and fresh water.

5. Maintenance - including specific maintenance tasks as well as spare parts and shop space requirements.

6. Damage Control - including attention to fire, buoyancy, wind, and wave damage and grounding.

7. Waste Management - including domestic sewage, solid wastes, industrial wastes, means of treatment and disposal, interface with the water supply system, waste reclamation, and protection and enhancement of the surrounding environment.

8. Power - including load requirements imposed by all other systems, power distribution, modular power back-ups, and type of power source to be employed.

9. Fuel - including requirements of other systems, average and peak usage rates, resupply frequencies, distribution of storage, and methods of resupply.

10. Transportation System - including internal and external logistics and personnel transport, normal and emergency conditions, possibilities of containerization, helicopters, various forms of surface craft, and submarines.

11. Public Health - including division of medical services between the floating community and Honolulu, disease prevention, in-patient and out-patient care, and emergency medical services.

12. Education - including education of the residents to floating city life, indoctrination of visitors, the potential of a marine university campus, and pre-college education of residents' children.

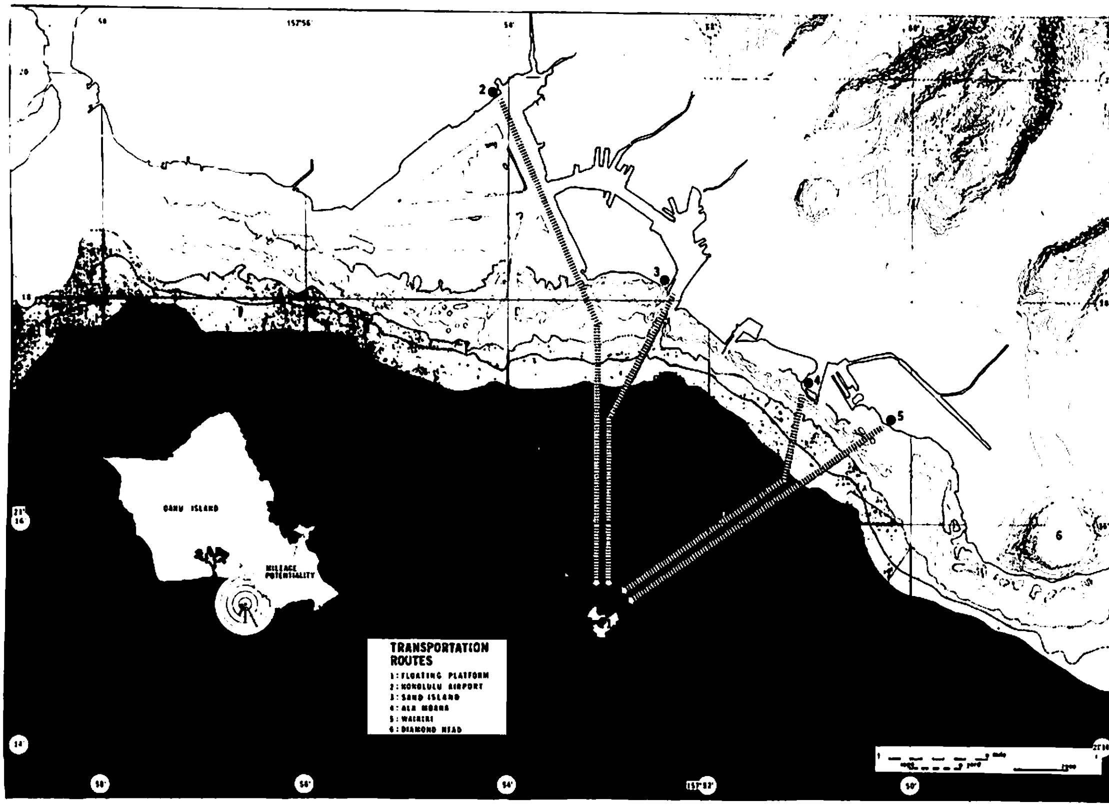
13. Recreation - including potential forms of indoor and outdoor recreation, sharing facilities with educational functions and dependencies of recreational requirements on population mixes.

14. Administration and Real-Time Control - including administrative and real-time control functions and their support requirements, automated or semi-automated control potentials and control interfaces with other systems.

This work was supported by term papers from Dr. Craven's Fall 1971 course in marine systems engineering (OE691) as well as a variety of other reference materials including M.D. Green's master's degree Ocean Engineering dissertation, "Position Control for Hawaii's Floating City." Parenthetically, the research leading to this M.A. dissertation was responsible for illuminating the attractiveness of dynamic position control as an alternative to a complex, high-safety factor, deep-water mooring system. The contained systems requirements and integration report will be completed during the early part of FY 1973 and published in limited quantity. It subsequently will support preliminary design and detailed integration of these floating city systems.

Environmental Analysis pertaining to the structure was led by Dr. Manley St. Denis, Professor of Ocean Engineering, University of Hawaii. The results along with their mathematical derivations are to be published in Volume V of Topics in Ocean Engineering by the Gulf Publishing Company. This report is as thorough as existing data will allow and so is somewhat voluminous. The following abstract treats only the main conclusions:

> "The city is to be located approximately three to five miles off the leeward shore of the island of Oahu in the Hawaiian Archipelago. Latitude and longitude are approximately



21° 15' N and 157° 50' W respectively. Trade winds prevail much of each year but are broken by periods of calm and southerly "Kona" winds. Tropical storms and hurricanes are infrequent and of short duration. Currents in this area appear to be tide-dominated and so show strong directional reversals. Long period swells enter the area from a northerly direction in winter and from a southerly direction in summer. The northerly swells are frequently refracted around Oahu. Shorter period waves of considerable size are, of course, generated by storm conditions. It must be emphasized that no long term recordings have been conducted at the site itself. Therefore, all data are extrapolated from the nearest appropriate site of recordation to the proposed floating city site.

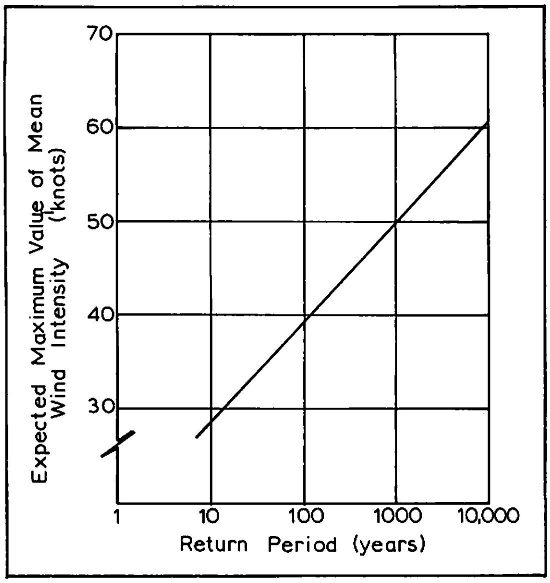
"The wind question is divided into Trade and Kona winds on the one hand and cyclonic storm winds on the other. A velocity of 22-27 knots appears to be the highest mean wind intensity occurring a total of only 1.3 percent of the year. Short term peak intensities are defined as the greatest one-minute averages recorded over a period of reference--one month in this case. The highest value recorded was 53 knots. Finally, peak gust intensity recorded at Honolulu International Airport (in 1959) was 58 knots. The long term trend mean wind intensity corresponding to a 100 year return period has been set at 39 knots with a 50% probability that the figure will be exceeded. The long term trend peak wind intensity with the same conditions has been set at 62 knots. A gross estimate of the long term trend gust intensity is 68 knots. The peak expected instantaneous value of winds generated in cyclonic storms is approximately 125 knots and peak sustained value is approximately 80 knots.

"Coupling of the wind, tide, and global circulation components of the highly complex current patterns observed in nearby areas yields an expectation of maximum surface current velocity in the realm of 175 cm/sec with a 100 year return period. The tidal component appears to be nearly 60 percent of the total so directions as well as velocities may be expected to vary with time and depth.

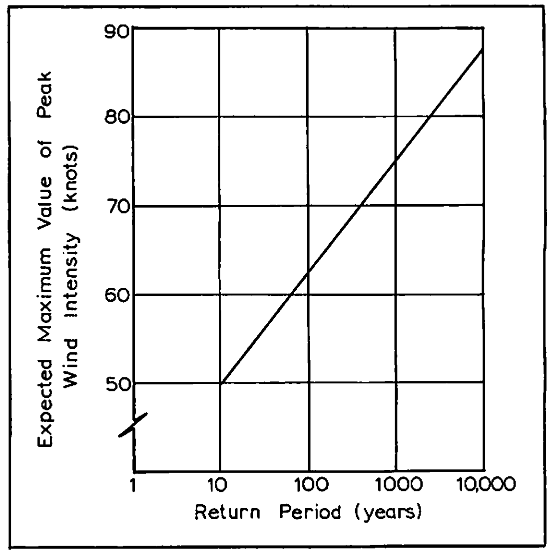
"Wave investigations lead to an expectation that the floating city will be exposed to waves having a significant height of 4 - 12 feet and a period of 5 - 8 seconds from ninety to ninety-five percent of the time during the summer months. Waves of the same sort will prevail slightly more than half the time during the winter months and will be interspersed with some dominance of 1 - 4 foot southern swells with periods ranging from 14 - 22 seconds about ten percent of the time during the winter. Infrequent wave height maxima are taken to be approximately 50 feet with periods in the realm of 16 seconds. These last figures are based on a 1000 year return period and, of course, would occur only during intense cyclonic activity."

Theoretical Investigations of the hydrostatic and hydrodynamic behavior of the core-ring and its components are being conducted by Dr. Ludwig Seidl, Associate Professor of Ocean Engineering, University of Hawaii. These investigations, aimed at deriving an optimum underbody configuration for the city, are based on mathematical simulations employing the FORTRAN IV compiler language and the University's IBM 360/65 digital computer system. The following excerpt from Dr. Seidl's report will serve as an introductory description of the research method being employed.

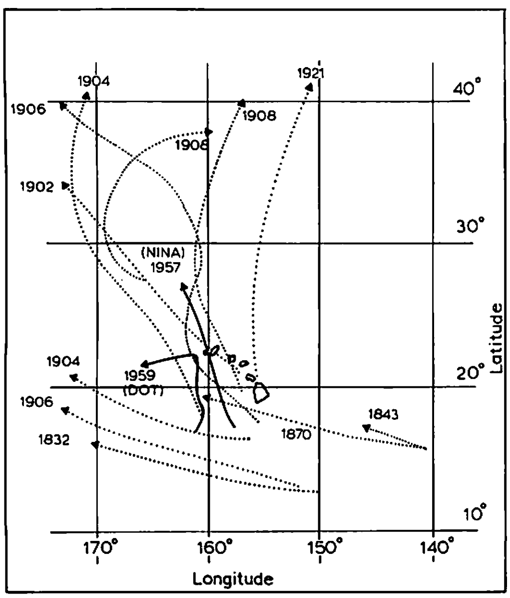
"The core-ring platform which is the object of this investigation is a radially symmetrical ring of identical floatation columns which are essentially spar buoys. There are ten such columns



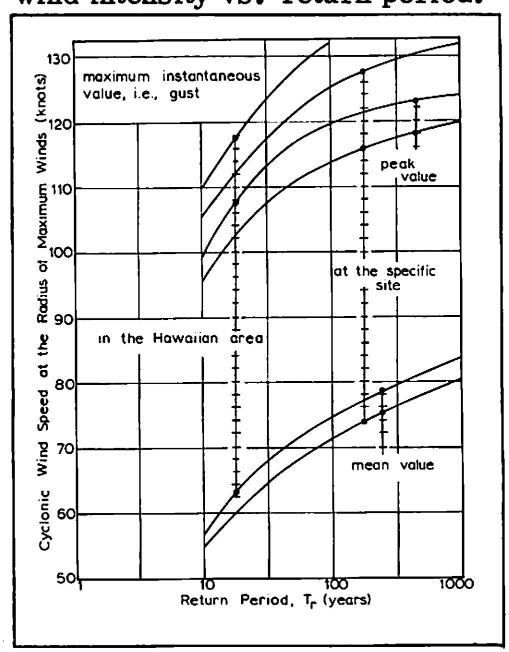
Expected maximum value of mean wind intensity vs. return period.



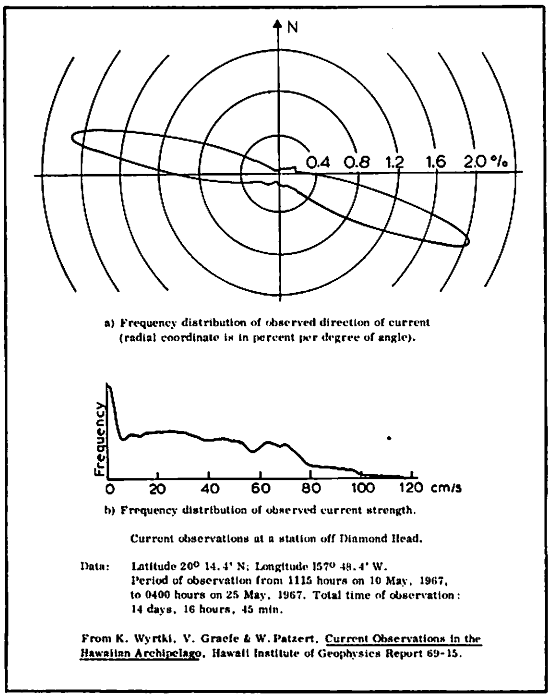
Expected maximum value of peak wind intensity vs. return period.



Tropical cyclone tracks in the Hawaiian area. Tracks of the tropical cyclone of 1921 and earlier years after S.S. Visher, courtesy of Bishop Museum.



Trend vs. return period of mean, peak and instantaneous maximum values of the maximum sustained cyclonic wind speed.



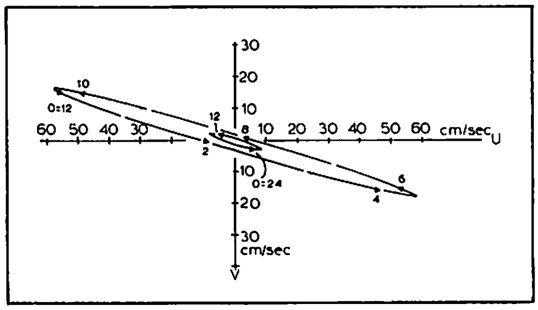
a) Frequency distribution of observed direction of current (radial coordinate is in percent per degree of angle).

b) Frequency distribution of observed current strength.

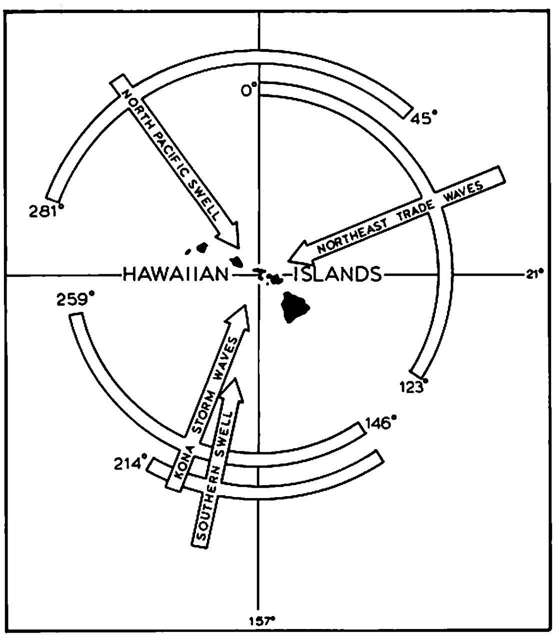
Current observations at a station off Diamond Head.

Data: Latitude 20° 14.4' N; Longitude 157° 48.4' W. Period of observation from 1115 hours on 10 May, 1967, to 0400 hours on 25 May, 1967. Total time of observation: 14 days, 16 hours, 45 min.

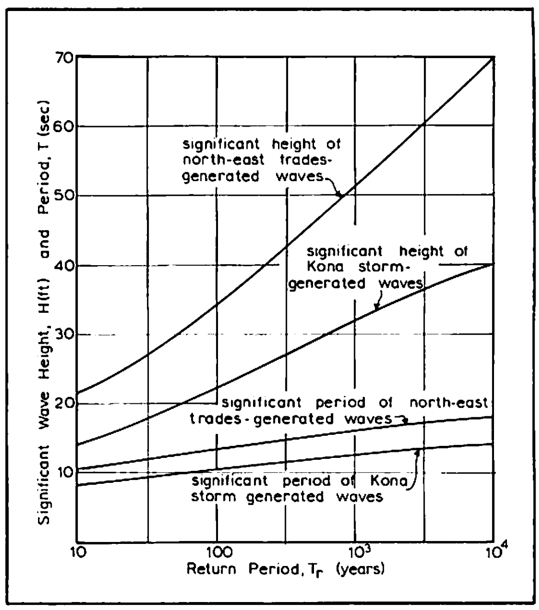
From K. Wyrtki, V. Graefe & W. Patzert, Current Observations in the Hawaiian Archipelago. Hawaii Institute of Geophysics Report 69-15.



Tidal current ellipses for semi-diurnal components at the station off Diamond Head. (Wyrtiki et al.)



Hawaiian wave pattern. From Moberly and Chamberlain.



Long term trend in significant wave height and period of wind-generated waves in the Hawaiian area.

equally spaced in the inner ring and twenty arranged in equidistant pairs in the outer ring. All columns are connected at their tops by a rigid deck and at the upper and lower extremities of their maximum dimensions by rather sizable horizontal tubes forming rigid connections with the columns themselves, the entire structure forming a rigid truss.

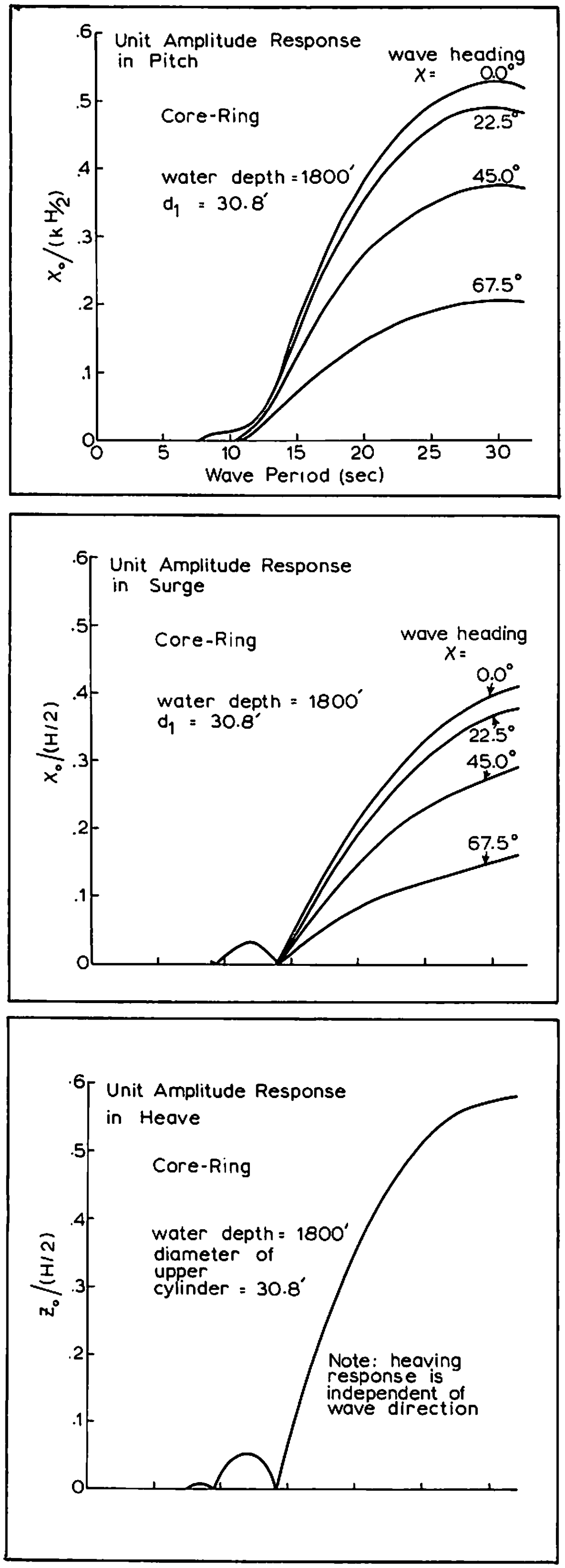
"However, it is impractical for a variety of reasons to build the entire structure as a unit. Therefore, the design concept features modularity. There are ten 36^{o} modules in the present engineering concept of the core-ring. Each of these is supported by three floatation columns, one at the narrow inner edge and two at the broader outer edge.

"It is necessary, of course, to investigate all six possible motions of the core-ring (heave, surge, sway, roll, pitch, and yaw). However, floating platforms such as the individual modules themselves or the core-ring in its entirety must be recognized as rigidly connected spar buoy clusters in which the heave response of the individual and coupled columns is an important or dominant factor in the determination of the five remaining motions. Therefore, considerable attention is devoted to the heave response of an individual column.

"Next it must be recognized that the individual modules must be seaworthy in moderate seas if they are to exist by themselves for even short periods of time and that they must also be quite stable in light to moderate seas if their assembly into the core-ring is to prove feasible. Thirdly, since assembly of the entire ring will take time, the partially assembled ring will be required to withstand possibly heavy seas with safety if not with absolute stability. Lastly, the ultimate objective, of course, is to derive an underbody configuration for the core-ring that will exhibit minimum motions and accelerations under all conditions.

"Therefore, this investigation proceeds from the responses of an individual column, optimizing heave response, through investigations of the resultant behavior of platforms having multiple columns in six degrees of freedom, and finally examines the expected behavior of the core-ring itself in six degrees of freedom in both regular and irregular seas."

During FY 1972, all equations of motion were derived, expressed in FORTRAN and checked out with representative data. The heave response of various faired and non-faired column configurations were then investigated to derive those configurations that would offer minimum heave in the full range of expected wave spectra while still affording conformance to other



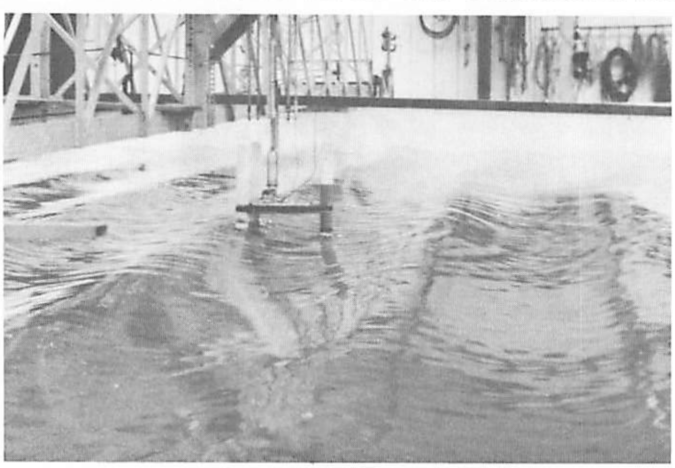
Graphic representations of calculated heave, surge, and pitch responses of the full scale core-ring.

design criteria. The candidate column configurations were then tested in module and core-ring assemblies to determine heave, surge, sway, roll, pitch, and yaw responses. This iterative theoretical investigation has thus far produced a preliminary recommendation for a column configuration with the following dimensions: (1) lower column diameter of eighty feet and length of 250 feet, and (2) upper column diameter of 38 feet and length of 120 feet to deck level and faired to the lower larger column.

At this juncture, with the mathematical tools now in hand, it seems desirable to carry these investigations still further into a wider range of alternative shapes. This will be done in FY 1973 along with the calibration of the theoretical models using empirical data obtained from the 1:20 scale model tests. Further work to be accomplished in FY 1973 will include investigations and calibrations with the 1:20 scale model of partial assemblies and various hypothetical damage conditions. These results will be published in a technical report, "Theoretical Investigations and Optimization of the Floating City Platform's Seakeeping Characteristics", to be issued in the spring of 1973.

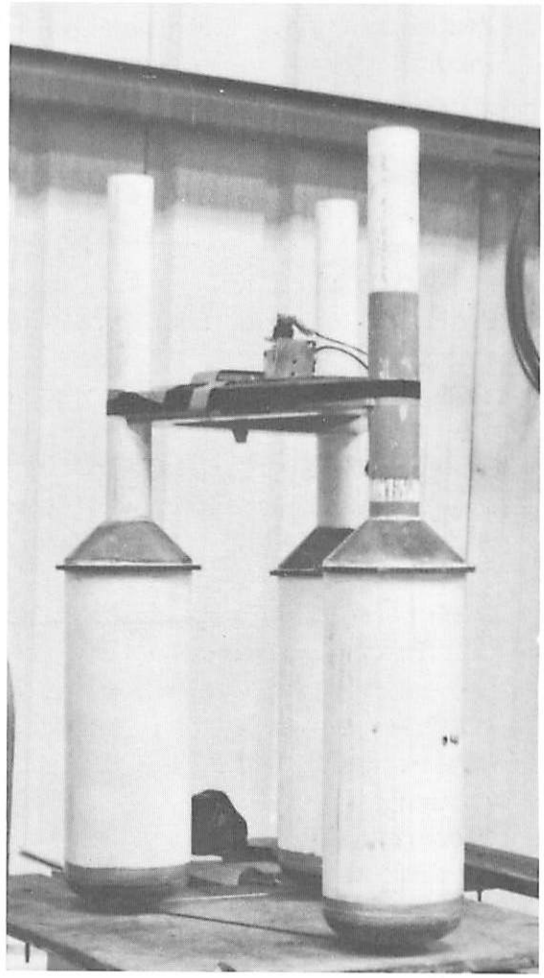
The fourth avenue of investigation, Scale Model Research, is based on two physical representations of the platform. The first is a small 1:150 model which can represent both single columns and one complete three-column module. It is appropriate to regular wave testing in available wave flumes. The second is a 1:20 scale model of the entire core-ring, fifty feet in diameter, fifteen feet in draft and displacing 150 tons. Its scale was selected to coincide with the waves available in Kaneohe Bay on Oahu's windware shore.

The 1:150 scale model was constructed simply and inexpensively of polyvinyl chloride (PVC) tubing and wood. It was fitted with adjustable internal ballast weights so that both displacements and center of gravity/ center of buoyancy (CB) ratios could be varied. It was also fabricated in such a way that it could be tested as either a faired or non-faired column configuration. An individual buoyancy column was tested in the small wave flume of the University of Hawaii's Look Laboratory. Empirical results obtained here showed acceptable agreement with theoretical results. For the full module tests, however, the Look



1:150 model at OTC

Laboratory flume was of insufficient size. So arrangements were made to obtain a larger wave flume operated by Off-Shore Technology Corporation (OTC) in California over a week-end at nominal cost. The results of this test were valuable, but not entirely conclusive. A more valid repetition of these tests would have required some modification to OTC's instruments plus considerable additional personnel time. So it was decided to proceed directly with the 1:20 scale model rather than to expend more of the limited budget on the 1:150 scale model work.



1:150 Model

The 1:20 scale model of the core-ring (50 ft diameter, 17.5 ft high, 50 tons dry and 150 tons ballasted), though only a portion of the FY 1972 work, is certainly its most visible manifestation. As such it has become a community symbol of floating city interest and support. The variety and value of this support may be inferred from the fact that twenty separate organizations and nearly three hundred individual volunteers contributed time, labor, equipment, materials, and facilities to the model's design, construction, transportation, and initial tests in Kaneohe Bay.

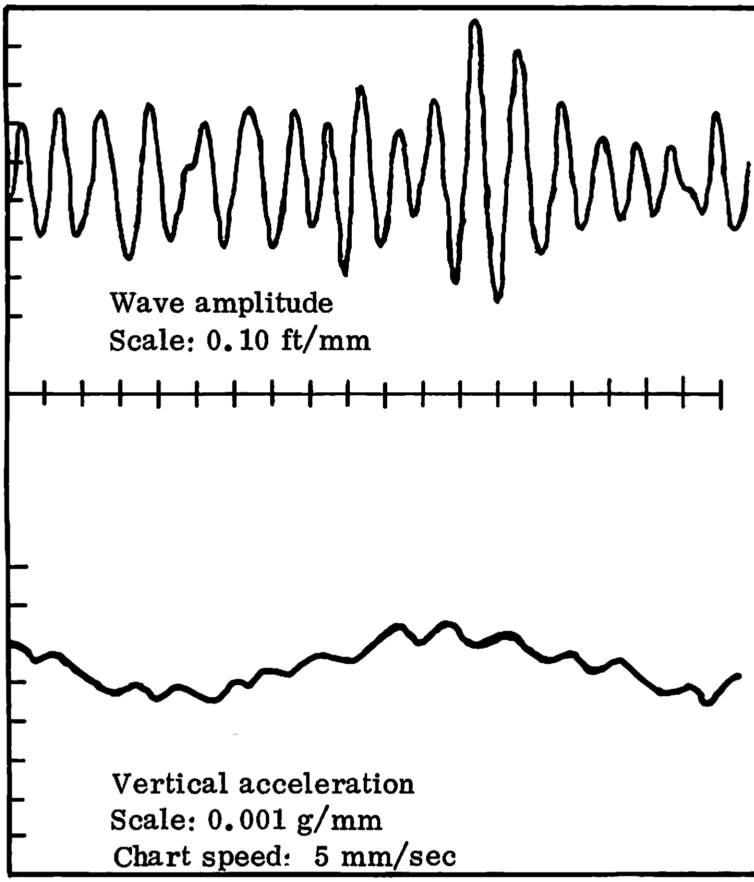
The model's design was derived in late 1971 after the early engineering work was completed. This design was subsequently modified with the assistance of Mr. Harold Martin of Hawaii Welding Inc. to minimize its fabrication costs. Fabrication by Hawaii Welding Inc. was begun in February of 1972 and was completed in mid-April. Finishing and shore assembly of the model took place on nearby land donated by HC&D Inc. This latter phase was accomplished, for the most part, by volunteer work and donated materials and equipment. On May 6, the ten 5-ton modules were loaded aboard a barge loaned by SERVRON-5 of COMSERVPAC and secured for transport. On May 9, one week later than the original target date set the previous October, the USS Quapaw of SERVRON-5 towed the model around the eastern tip of Oahu to Kaneohe Bay. Off-loading was completed the following day and testing began with in-water assembly trials the following week.

Construction, finishing and pre-assembly of the 1:20 core-ring scale model in the Sand Island industrial district of Oahu--February, March, and April 1972.

1:20 scale model dissassembly, transport to Kaneohe Bay, reassembly "at sea," and initial testing--May, June and July 1972.

Both the University of Washington and the Naval Air Systems Command (NAVAIR) contributed instrumentation and data recording equipment along with field representatives. The remainder of May and early June were spent in completing the initial in-water assembly and ballasting control experiments; initial towing experiments; installing, calibrating, and modifying instrumentation; and in making and testing ancillary instrumentation.

By mid-June the model was moored at data station #1 in the southeast part of Kaneohe Bay. Normally, June in Hawaii is a month of brisk trade winds with sustained velocities from 15 - 25 mph. These are the winds necessary to generate appropriate waves and in part were the reason for the June test schedule. As one might suspect, this year brisk trades were sporadic and infrequent during June. Nonetheless, by early July an initial set of test data had been obtained at data station #1. These data agreed, in general, with the theory-based predictions of minimum motion induced by short period waves. During the first week in July it was decided to transfer the model to data station #2 where longer period waves were available.



Copy of a chart record containing a typical wave train and 1:20 scale model heave response sensed by a single accelerometer. The long (≈15 sec) component results from wind induced pitch at the model's natural period coupled with some displacement of this accelerometer from the model's C.G. The short (≈2 sec) component is the model's wave induced heave response.

Prior to the first towing tests, the program staff considered the advisability of stoppering the deck level openings of the thirty floatation columns during tows. Two things should be mentioned here. First, in this partial expression of the platform's design it is necessary that these openings exist during motion tests to accommodate the ballast system. Second, building and utilizing removable closures is, in light of budgetary and time restrictions, relatively costly. For these reasons it was decided to risk the deck level openings. This risk was felt to be minimal so long as care was exercised in towing. Note here that (1) the full-sized core-ring would not and could not be towed as the model is, and (2) the model represents only a part of the full size core-ring since its columns do not extend upward beyond deck level. During the first several towing operations the calculated risk proved justified; the model only once approaching a dangerous pitch angle when an early version of the four-point towing bridle failed. On the July 7 transfer from data station #1 to #2, however, an error in procedure occurred. This caused the model to be released from its mooring before the towboat had attained a towing position. Subsequent recovery attempts apparently caused some surging between the towboat and the model (possibly a result of elastic coupling between the two) which in turn set up extreme pitching oscillations in the model. Before these oscillations could be brought under control, the deck level column openings admitted enough water to swamp the model and it sank in forty feet of water near data station #1. Thanks to prompt action on the part of COMSERVPAC, however, the model was re-floated with no significant structural damage by July 17.

This incident, though it inflicted only minor damage to the model and its overall test program, nevertheless illuminates the extremely small percentage of reserve buoyancy characteristic of these semi-submersible structures. It therefore brings out quite strongly the need to (1) provide maximum reserve buoyancy within the basic design of the structure, and (2) explore and evaluate all potential means of preventing the occurrence of instability that could result from either hull damage or extreme environmental conditions. The preliminary engineering work, then, must focus on prevention of hull damage through collision or internal accidents, the prevention of significant primary buoyancy loss should hull damage occur and the provision of maximum reserve buoyancy should hull damage result in loss of primary buoyancy.

The FY 1972 Preliminary Engineering inquiries were directed toward four basic and mutually dependent questions. What is the best overall structure? What should be the construction material? What should be the construction method? How is this structure to maintain its station?

These four aspects may be thought of as parameters of a problem in optimization. That is, they all influence each other to a large degree, so that the final configuration of the city's underbody will be determined as the "best" combination of all four parameters. By "best", we mean the optimum cost, safety, utility, and "designability". And by "designability", we mean that current engineering methods must be capable of predicting the structure's behavior under all expected conditions. For instance, we now have from Dr. Seidl's work a variety of related shapes, some of which are hydrodynamically more stable than others. From the better shapes we must select one that is easy to build, susceptible to structural stress analysis by available methods, and has low drag coefficients for the sake of a practical positioning system. And, at the same time, it must satisfy the functional requirements of the city itself.

Earlier in this report it was mentioned that our FY 1972 engineering investigations accepted the general form of the structure derived from the work of its predecessors and sought simultaneously to determine its feasibility while optimizing it. The engineer will not question the basic design approach since the constant radius convexities it represents have long been accepted as the most workable solution to hydrostatic pressure problems. The only question remaining is whether or not the main buoyancy chambers might be arranged horizontally rather than vertically. And questions of construction feasibility coupled with subsurface volume requirements appear to support the vertical arrangement.

Structural analyses along with cost and material availability considerations reveal two candidate construction materials. One is steel; the other concrete. Either appears adequate technically speaking. So the selection should be based on broader cost/benefit considerations and these, in turn, can be influenced by locale, which is the case with Hawaii.

Hawaii's concrete industry is large and vigorous and, for the most part, employs raw materials obtained locally. Not so with its steel industry--which must rely wholly on imported raw materials or prefabricated components. So, concrete as a basic construction material was investigated with the help and support of Hawaii's Concrete and Cement Products Industry (CCPI). In late 1971, Mr. Watson Clifford, Manager of Product Engineering for HC&D, Inc.--one of Hawaii's major concrete firms--and chairman of the CCPI Technical Committee, compiled a report which summarized the use and performance of concrete in sea water. This report was of great help in the preliminary engineering investigations and will be published as an appendix to the preliminary engineering report to be issued by the end of next year's work.

With the results of Mr. Clifford's work in hand, Dr. St. Denis, Mr. Rothwell and Mr. James Smith, a master of arts candidate in Ocean

Engineering, began strength-to-weight ratio calculations for various concrete mix compression force resistances. It was determined that low grade (3000 psi) concrete could not be employed in the structure since the weight of it required to produce a structure of adequate strength would be greater than its displacement. Then 6000 psi concrete, which is presently manufactured in large volumes in Hawaii, was evaluated. It was found that, for a load factor of 0.45 f'_c, concrete of $f'_c = 6000$ psi and 155 p/cf produced a ratio of underbody structural weight to displacement of one to four. This leaves 75 percent of the available buoyancy for payload requirements imposed by the city's functional requirements (derived from the contained systems analysis mentioned earlier). An initial summation of these latter weights indicates that there should be a reserve buoyancy, with all systems installed, of about twenty percent.

In addition, concrete tends to increase in strength with age and with extended submersion in sea water. Mr. Clifford's investigations indicate few problems with changes in strength of the concrete or with corrosion of reinforcing steel as long as good quality control and adequate covering are provided; and Hawaiian concrete, being relatively non-reactive with saline water, requires no special protection or maintenance against corrosion influences once submerged. Therefore, concrete appears to be the prime candidate for construction in Hawaii. This does not necessarily mean that steel would not be the most cost/beneficial material in a locale where its availability is greater and its cost lower.

Concomitant with the material selection inquiries, shell and joint structural questions were explored. With strong support from the U.S. Navy and the University's Center for Engineering Research (CER), a large automated finite element structural analysis system--NASTRAN--was obtained and installed in the University of Hawaii's Computing Center. NASTRAN was developed by the National Aeronautics and Space Administration (NASA) at a cost of several million dollars. Its local installation and checkout were followed by a two-week course in its use conducted under CER auspices and taught by Mr. Petro Matula of the Naval Facilities Command. As a result of this activity it appears that automated support for complete structural analysis of the entire floating city is now in operation in Hawaii along with a core group of personnel trained in its use.

At this point it must be noted that the initial selection of 6000 psi concrete is dependent on two as yet unproven assumptions. The first is that the 20-foot diameter horizontal strut loadings can be held to allowable levels. Conditions which would appear to produce maximum loadings are assembly procedures, large long-period waves, and partial flooding caused by collision or other structural damage. The second is that effective designs for inter-module horizontal strut joints can be developed. However, in this respect, the preliminary work offers encouragement. An automated space-frame model of the structure, when subjected to extreme loadings, indicated that (1) gross joint stresses exceeded allowable tolerances only if one floatation column of a module were to be completely flooded, (2) all other structural stresses were within acceptable limits, and (3) these responses could be obtained with the average shell wall thickness of 24 inches, which provided the buoyancy coefficients cited previously.

Load Summary for One Module
(thousands of pounds)

Portion of Structure	Structural and Mechanical Weight	Live Load[4]
Superstructure[1]		
Main Columns	13,316	3,696
Enclosed Space	25,402	30,240
Structural Decks	4,725	3,000
Main Deck Structure[2]	26,775	10,350
Columns below Deck	6,657	1,848
Structural Shell of Underbody[3]	46,926	
Framing and Decks	15,000	21,000
TOTAL	138,801	70,134
Total Live plus Dead		208,935
L.W.L. Displacement		240,000
Allowance for Fuel & Water Storage		11,065
Ballast		20,000[5]

Notes:
1. Steel and lightweight concrete
2. Concrete
3. Concrete
4. At superstructure, live load deduction of 40% is allowed for 16 floors
5. Minimum allowable ballast is governed by damage control requirements

Logistics and methodology for the construction of a floating structure of this magnitude most certainly constitute one of its most fascinating problems. In Hawaii at least there are no quiet harbors with a depth even approaching the draft of the floating city. Towing even one module at its design load water line (LWL) not only would require a very large energy expenditure but, because of the small amount of reserve buoyancy inherent in such a structure, would involve some operational hazards. So complete construction of individual modules in a harbor appears unpromising unless they might somehow be barged to the assembly and installation site.

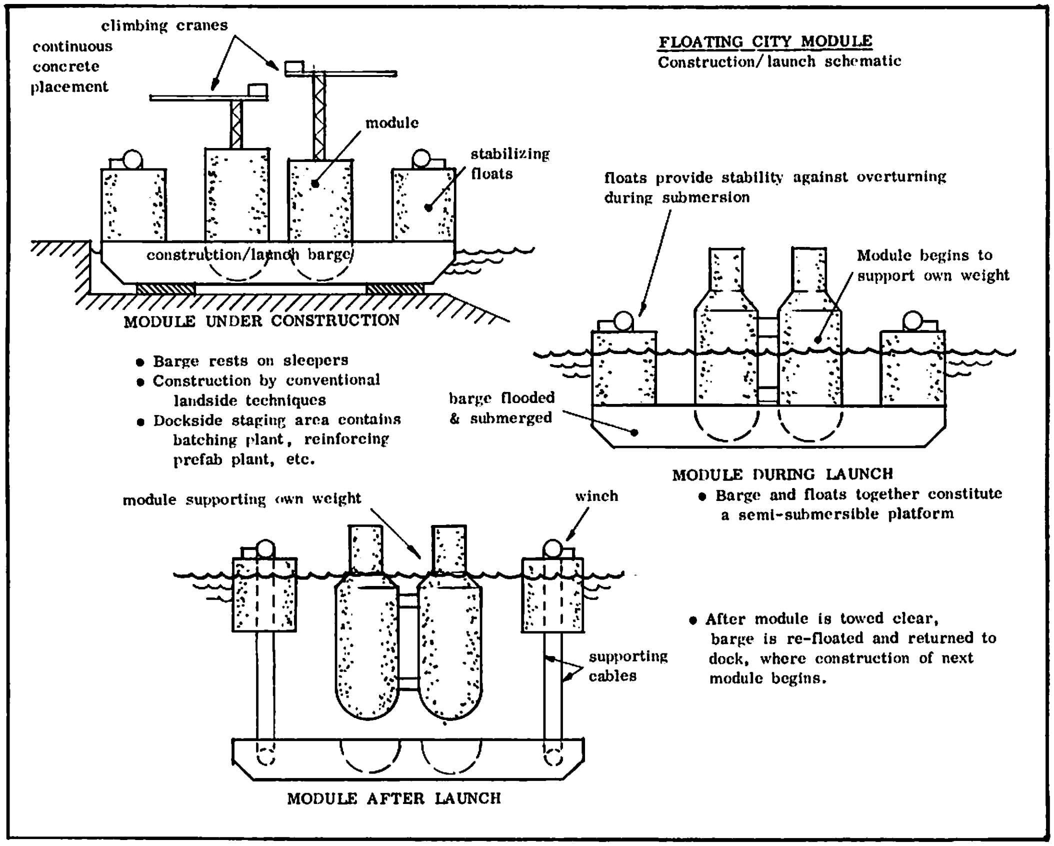
Other methods explored involve whole or partial assembly and construction at sea. For the first structure to be produced, these approaches rapidly lose attractiveness as one ponders such problems as the logistics of equipment and material supply to an off-shore location, installation of heavy and complex equipment from a surface-connected ship in open ocean conditions, the necessity of developing special floating equipment and techniques for fabrication and quality assurance, the potential of delays caused by extreme environmental conditions and so forth.

Still other highly interactive considerations that must be included in an investigation of the construction method are:

- Insurance on the structure, the construction equipment, and the crew.
- Full exploitation of the modular redundancy inherent in the structure's design through maximum employment of mass production technology.
- Financing and depreciation of construction equipment.
- Long-term construction scheduling designed to minimize adverse short and long term impacts on the local construction industry and its labor force.
- Overall equipment and personnel safety requirements.
- Minimum employment of untried construction and placement methods and equipment.

At present, we are developing an in-depth appreciation of the problem through a variety of trade-off analyses and the development of first approximation construction scenarios that result from alternative construction methods. The accompanying table contains a simplified representation of the conclusions reached so far. We are, then, led to

SIZE OF ELEMENT / CONSTRUCTION METHOD	BUILD ASHORE	BUILD IN GRAVING DOCK	BUILD ON SUBMERSIBLE BARGE	BUILD AT SEA
SMALL ELEMENTS (less than one Floatation Chamber)	<u>IMPRACTICAL:</u> inwater assembly of parts before buoyancy is attained. Equipment installation problems, excessive work at sea during assembly.	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
ONE FLOATATION CHAMBER (translate after launch)	<u>IMPRACTICAL:</u> equipment installation problems, excessive work at sea during assembly stage.		NOT APPLICABLE	<u>IMPRACTICAL:</u> high cost of at sea construction; elements unstable during construction; high risk of loss due to long exposure to adverse environmental conditions while structure is incomplete.
ONE MODULE	<u>IMPRACTICAL:</u> no deep water sites available, extremely high cost to produce adequate site by dredging, also great environmental damage from dredging operations, excessive structural stresses during launch.		<u>PRACTICAL:</u> sites are available, construction equipment cost amortized by multiple use, element in a fully stable ocean platform at launch, almost all construction and equipment installation is done "on land".	
MANY OR ALL MODULES			<u>IMPRACTICAL:</u> extremely high cost; lack of sites.	



a serious examination of the feasibility of constructing individual modules on very large, relatively shallow draft submersible barges that would "fit" a shore based recess much as a conventional ferry boat fits its terminals. Such a barge would be ballasted down to rest on submerged supports making it level with adjacent land during construction of modules. It would then, with the completed module aboard, be ballasted up off the support for towing to the open sea site. At the site, it would be submerged until the module it contained gained its own buoyancy. After the module was thus removed, the barge would be towed back to its terminal to begin construction of another module.

Though similar techniques have proven workable on much smaller scales and with different classes of structures, there is much we must still learn about this proposed application. Further work in this realm is scheduled for FY 1973. It will involve more extensive engineering analyses, theoretical simulation and tests employing the 1:20 scale model and either the Naval Undersea Center's Launch and Recovery Platform (LARP) or Makai Range's Launch, Recovery and Transfer Vehicle (LRTV).

Being afloat, the city must control its position against wind, tide, and current forces. Two basic methods for attaining this objective have been considered and the results are somewhat surprising. The two methods are (1) mooring to the ocean bottom, and (2) continuous self propulsion (dynamic positioning). Apart from cost, self propulsion appears preferable for the following reasons. First, it provides mobility (including rotation). Second, maneuverability--in case position cannot be maintained--is entirely feasible. Third, maintenance of the system is far more practical. Fourth, it provides an opportunity to provide righting moments against wind or, alternatively, freedom from overturning moments caused by random (uncontrollable) location of the resultant combinations of wind and current forces. Lastly, because of the rotation freedom, it offers designers an opportunity to achieve drag reduction by adopting an oriented shape for the underbody, since it includes the capability to vary "angle of attack".

Although various mooring systems have been studied, of these only multipart taut or catenary moorings with radial symmetry and large scope appear practical. Such mooring systems would require many miles of very large cable and enormous anchors; since they must be designed to withstand the rare peak forces which may be imposed in, say, the 1000 year storm. This approach appears hazardous in light of our present knowledge since our estimates of peak current and wind velocities are statistical projections supported by a very narrow data base and cannot be considered entirely reliable; and, after the mooring lines have been in the water for a period of time, their condition will not be known exactly. It must be recognized too that the consequences of failure of a passive mooring system are probably irreversible, and therefore dictate a design which cannot fail. At present, we do not believe this goal can be achieved within anything approaching acceptable cost.

But self propulsion offers a remedy for each of the problems inherent in passive mooring. If peak forces exceed those predicted, the city can "give ground" while remaining under control, returning to station after conditions have returned to normal. All parts of a self-propulsion system are easily available for periodic maintenance and repair. And the system is still operable even if some units are out of service since ten propulsion units are contemplated. We find, too, that power requirements are usually small, apparently less than five percent of the power generation capacity required by the city itself. Peak power requirements, based on the environmental analyses, are not more than seventy or eighty percent of the city's planned power capacity. Thus, on the rare occasions of peak demand, the city might afford to undergo emergency diversion of power to its propulsion. Finally, the only significant additions for propulsion are ten propulsion units and their controls, at a cost probably much less than the installation of adequate mooring systems.

These conclusions are, of course, preliminary. They will undergo further analysis in FY 1973.

In summary, we feel the progress the program has shown to date is quite impressive. The $85,000 first year Sea Grant funding has now been matched more than three and a half times by other contributions. Preliminary engineering of the structure is well underway and there appears to be a chance that complete preliminary engineering documentation can be produced by the end of the second year of Sea Grant funding. Both the theoretical and empirical investigations so far support the feasibility of the concept and we see abundant evidence that we are well on the way to an optimization of the underbody configuration.

That the program has established itself in the local eye is evident from repeated coverage by local newspapers, television, and radio; from the mass of volunteer workers it has attracted; and from the recent diminution of counterculture dissidence it has enjoyed. That it has also done this at the national and international level is evident from our continuous stream of visitors from around the world and from the fact that it has received newspaper and television coverage in Japan and Holland as well as on the U.S. mainland.

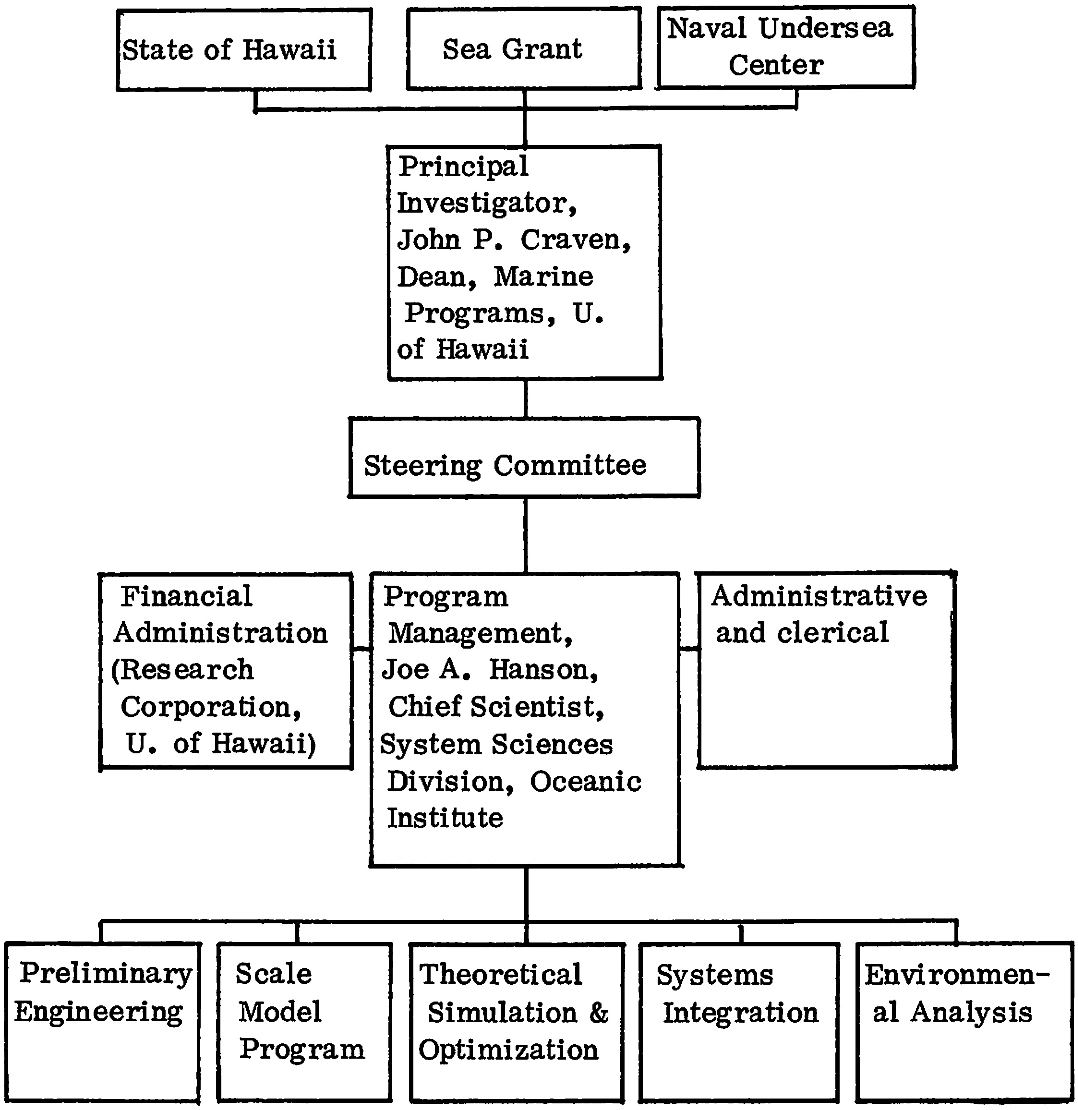
We hesitate to assert that we have developed by now the broad base of resident knowledge toward which we strive. However, we feel justified in asking to be judged by our accomplishments and in mentioning that these accomplishments result almost entirely from cooperation among local Hawaiian institutions including business, local government, federal government agencies, and the academic community.

	Environmental Analysis	Systems Integration Studies	Theoretical Hydrodynamics Studies	Scale Model Research	Preliminary Engineering
ACCOMPLISHMENTS	1. Acquisition and review of all existing data and reports pertinent to the selected site. 2. Reduction and analysis of pertinent data followed by extrapolation and interpolation to the selected site. 3. Writing and editing of final report.	1. Completion of Students' reports - OE 691. 2. Acquisition and review of reports and standards covering systems similar to Floating City systems. 3. Development of systems interface matrix. 4. Derivation of characteristics, sizing estimates, and space and weight requirements. 5. Initial draft of final report.	1. Development of response operators and coupled equations of motion in six degrees of freedom for various underbody configurations. 2. Completion and checkout of computer programs capable of analysing the structure's buoyant body responses in regular and irregular seas. 3. Prediction of responses of 1:150 model, 1:20 model, and full scale prototype - partially complete. 4. First approximation of optimum column shape. 5. Draft of final report 70 percent complete.	1. Design, construction and initial testing of: a. 1:150 scale model of single column and single module. b. 1:20 scale model of single modules and core-ring. 2. Preliminary data reduction.	1. Installation of NASTRAN on IBM 360/65 system of UH Computing Center 2. Literature survey of concrete in sea water. 3. Tentative selection of 6000 psi, post tensioned concrete as the basic structural material. 4. Preliminary weight and buoyancy calculations. 5. Derivation of one approach to the construction method. 6. Analysis of station keeping alternatives. 7. Initial stress calculations.
TECHNICAL REPORT	"The Winds, Currents, and Waves at the Proposed Site of Hawaii's Floating City," by M. St. Denis, D. Eng., Vol. 5, Topics in Ocean Engineering, Gulf Publishing Company, Fall 1972 (est.)	"Preliminary Analysis of Floating City Systems Requirements," by M. A. Lucas and G. N. Rothwell, Floating City Program Office - Fall 1972 (est.)	"Theoretical Investigations and Optimization of the Floating City Platform's Seakeeping Characteristics," by L. H. Seidl, Ph.D., Floating City Program Office - Spring 1973 (est.)	"Hawaii's Floating City Scale Model Research Program," by G. N. Rothwell et al., Floating City Program Office - Spring 1973 (est.)	"Hawaii's Floating City - Preliminary Engineering Specifications," by M. St. Denis, G. N. Rothwell, et al., Floating City Program Office - Fall 1973 (est.)

Summary of technical accomplishments - FY 1972

Institutional Relationships

As a Sea Grant program this officially has been a joint effort of the University of Hawaii and the Oceanic Institute; and this official structure indeed describes a major portion of the core program's organization.



Nonetheless, large components of the whole consisted of enthusiastic participation from a wide range of federal, state and non-government organizations and individuals, and these components do not lend themselves to representation in a classical organization chart. For example, the Naval Undersea Center's Hawaii Laboratory is representative of at least a dozen organizations in that the magnitude of the non-cash part of its participation was crucial to the program's impressive progress. Yet its only official representation in the organization (other than as a funding source) is through the Steering Committee. Then there is another category of individual and organizational program associates who were not even represented on the Steering Committee. These associates simply helped where and when they were required without thought of monetary remuneration. Thus the form and functions of the program evolved as the work evolved. It seems that modern management science lacks the tools to express diagrammatically the organically adaptive growth phenomenon that can occur when a new and exciting idea develops in a true community. Therefore, it seems that the best way we can accomplish this here is to list the Steering Committee members and their affiliations and then to direct the reader's attention to the financial summary which, it seems, tells the story of institutional relationships as well as it can be told short of a voluminous program biography.

Steering Committee Members

Dr. Charles Bretschneider	Department of Ocean Engineering, University of Hawaii
Dr. Hugh Burgess	Department of Architecture, University of Hawaii
Watson Clifford	HC&D, Inc.
Donald Cole	Informatics, Inc.
Dr. John P. Craven	Dean, Marine Programs University of Hawaii
Dr. Jack Davidson	Sea Grant Programs University of Hawaii
Frank Gregory	General Manager, Jorgensen Steel Co.
Joe A. Hanson	Oceanic Institute (chairman)
Jack Harmon	Jakus Associates
John O. Lindquist	Naval Undersea Center
James Leslie	Independent artist
Harold Martin	Hawaii Welding, Inc.
Dr. T.M. Miura	Office of Environmental Quality Control, State of Hawaii
Dr. Robert Palmer	Look Laboratory, University of Hawaii

Dr. Morton Rosenberg	Graduate Research Division, University of Hawaii
Guy N. Rothwell	Oceanic Institute
Dr. Ludwig Seidl	Department of Ocean Engineering, University of Hawaii
E.R. Simmerer	HC&D, Inc.
James Stacey	GASPRO, Inc.
Dr. Manley St. Denis	Department of Ocean Engineering, University of Hawaii
John Wheaton	Director, Corporate Development, Dillingham Corporation
George Wilkins	Naval Undersea Center
Colonel Dudley Williams	AMIS, USARPAC (Fort Shafter)

While it is impossible to list all of the hundreds of persons who have participated in the program, it would be unfair to omit mention of three Ocean Engineering graduate students. These three have immersed themselves in the program since its inception. They have grown with it and will most assuredly be heard from in the future. They are M. Dale Green, Steven B. Ribakoff, and James M. Smith.

Financial Summary

The FY 1972 program received monetary contributions from three sources. These were Sea Grant #2-35243 for $85,000 which was established as Project 191 within the Research Corporation of the University of Hawaii (RCUH); a $12,900 contract with the Hawaii Laboratory of the Naval Undersea Center (NUC) which was established as RCUH Project 878; and $27,000 from Task Order #25 of the Hawaii State Office of the Marine Affairs Coordinator, which was established as RCUH Project 882. Of this latter amount only $8,411.40 has been committed to date. The remainder will be expended during FY 1973. The total monetary expenditure of the program between September 1971 and August 1972, then, is $106,311.40. It must be noted here that this report was prepared in mid-August 1972. So there may be minor discrepancies between figures reported here and RCUH account records as of August 31, 1972.

The financial summary given in the following pages is divided into three basic categories: (1) federal contributions, (2) Hawaii state contributions, and (3) non-government contributions. In this summary, the cash contributions discussed in the preceding paragraph are identified.

All other contributions consisted of non-cash items such as professional services, labor, free use of facilities and capital equipment, free services and materials, or in some cases discounts on the above items. It goes without saying that we have found it necessary to estimate the monetary value of some of these. We have attempted to maintain conservatism in these estimates. For example, when standard values were not available, a unit time labor value of $2.00/hour was employed. In most cases, however, the organization involved was able to provide the monetary value of its contribution using its own established costing procedures.

We are pleased with this financial summary since we feel it clearly depicts the depth and breadth of community support the program enjoys and that it exemplifies both the letter and intent of Sea Grant policy.

	Contributions	Expenditures	Funds Remaining
A. Federal Contributions:			
1. Department of Commerce: Sea Grant FY 1972; cash (RCUH Project 191)	$ 85,000.00	$ 89,230.38	$ -4,230.38
2. U.S. Navy:			
a. Naval Undersea Center; personnel services, materials & capital equipment	24,750.00	24,750.00	-0-
b. Naval Undersea Center: cash (RCUH Project 878)	12,900.00	6,843.96	6,056.04
c. Naval Ship Research & Development Center: personnel services, materials & capital equipment	2,950.00	2,950.00	-0-

	d. Commander Service Force Pacific: personnel services, materials & capital equipment	$ 48,017.88	$ 48,017.88	-0-
	e. Naval Air Systems Command: personnel services, materials & capital equipment	15,000.00	15,000.00	-0-
	f. Miscellaneous Sources: materials & capital equipment	23,996.15	23,996.15	-0-
3.	U.S. Coast Guard: personnel services, materials & capital equipment	160.00	160.00	-0-
	TOTAL FEDERAL CONTRIBUTIONS	$212,774.03	$210,948.37	$ 1,825.66

B. <u>State Contributions</u>:

1.	Marine Affairs Coordinator:			
	a. Early committee support	50,000.00	50,000.00	-0-
	b. MAC Task Order 25: cash (RCUH Project 882)	27,000.00	8,411.40	18,588.60
2.	University of Hawaii: personnel services, materials & capital equipment	26,255.00	26,255.00	-0-

3. State Department of Transportation: materials & capital equipment	$ 250.00	$ 250.00	-0-
TOTAL STATE CONTRIBUTIONS	$103,505.00	$ 84,916.40	$ 18,588.60

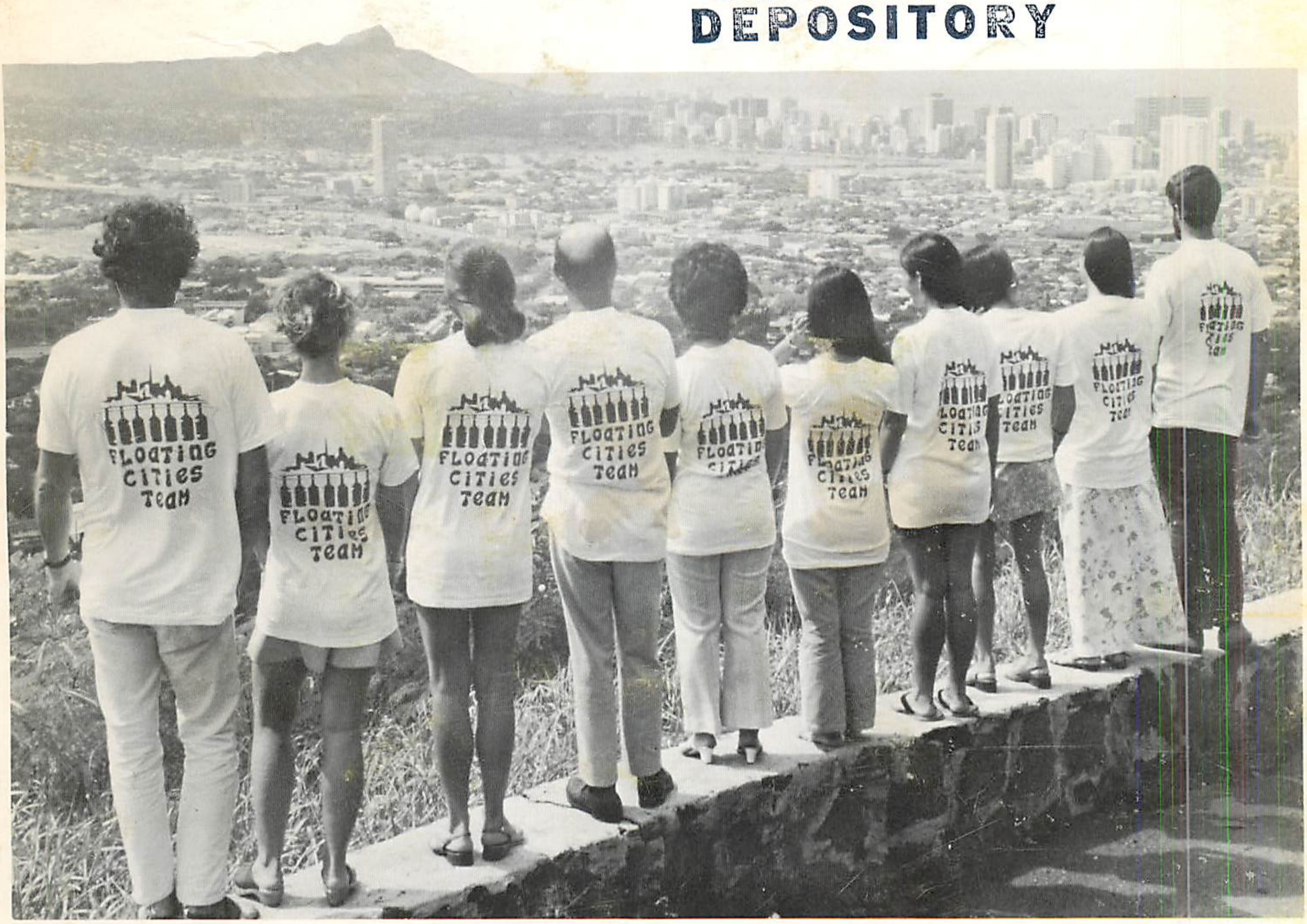
C. <u>Non-Government Contributions</u>:

1. Industrial:

a. Dillingham Corporation: personnel services	1,250.00	1,250.00	-0-
b. Gaspro, Inc.: personnel services	1,500.00	1,500.00	-0-
c. Informatics, Inc.: personnel services	1,375.00	1,375.00	-0-
d. Cement & Concrete Products Industry of Hawaii: personnel services	1,250.00	1,250.00	-0-
e. Hawaii Welding: personnel services, materials and capital equipment	6,736.00	6.736.00	-0-
f. HC&D: personnel services, materials & capital equipment	7,000.00	7,000.00	-0-
g. Control Data Corp.: material & capital equipment	100.00	100.00	-0-

h. Jakus Associates: personnel services, materials & capital equipment	$ 1,600.00	$ 1,600.00	-0-
i. Kentron Hawaii: personnel services, materials & capital equipment	500.00	500.00	-0-
j. Hawaii Dredging: personnel services, materials & capital equipment	2,159.00	2,159.00	-0-
k. Jorgensen Steel Co.: materials & capital equipment	2,782.00	2,782.00	-0-
2. Private:			
a. Leeward College Student Welders: personnel services	700.00	700.00	-0-
b. Volunteer Labor: 1:20 scale model construction	4,480.00	4,480.00	-0-
c. James Leslie: personnel services	250.00	250.00	-0-
d. Volunteer Divers-University of Hawaii Aquanauts: personnel services, materials & capital equipment	250.00	250.00	-0-

3. Private Educational/ Research Institutions:			
a. Oceanic Institute	$ 43,721.86	$ 43,721.86	-0-
TOTAL NON-GOVERNMENT CONTRIBUTIONS	$ 75,653.86	$ 75,653.86	-0-
TOTAL SUPPORT	$391,932.89	$371,518.63	$ 20,414.26


FLOATING CITIES TEAM