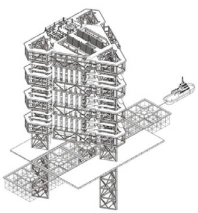
Floating Settlements

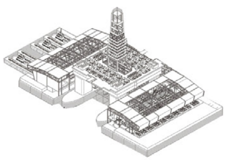
dr. joseph lim
design research
studios

architecture
nus

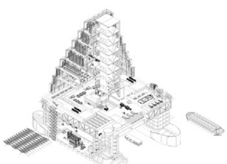
FOOD



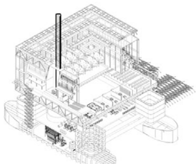
FISH FARM AND PROCESSING FACILITY



FISH DISTRIBUTION + WHOLESALE MARKET

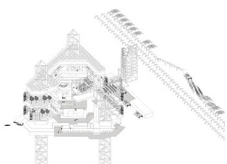


VERTICAL FARM + HOTEL

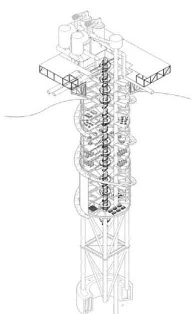


ORCHARD + CREMATION FACILITY

ENERGY



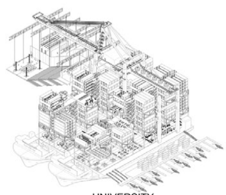
KELP PROCESSING FACILITY + DIVING CENTER



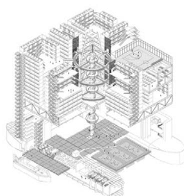
OTEC ENERGY PRODUCTION + UNDERWATER AQUARIUM

COMMUNITY

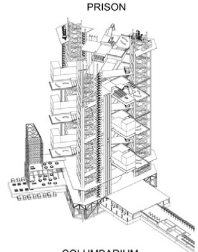
HOSPITAL



UNIVERSITY

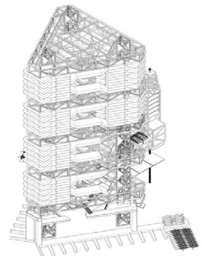


PRISON

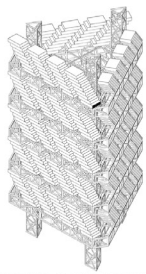


COLUMBARIUM

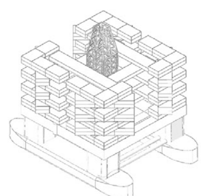
RESIDENTIAL



RESIDENTIAL JACKUP
CAPACITY: 3000
NEAR SHORE OPTION
MAX. SEA DEPTH 40M

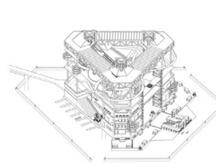


RESIDENTIAL JACKUP (TERRACING)
CAPACITY: 3000
NEAR SHORE OPTION
MAX. SEA DEPTH 40M



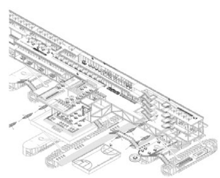
RESIDENTIAL SEMISUB
CAPACITY: 1400
DEEP SEA OPTION
FLOATING

RECREATION

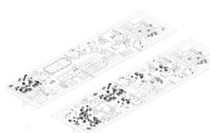


WATER THEME PARK

TREE TOP WALK + WILDLIFE OBSERVATORY

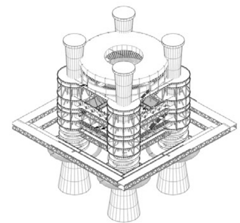


MARKET BRIDGE

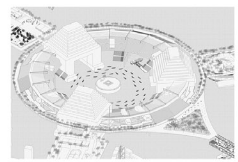


PARK LAND BARGE

GOVERNANCE



PARLIAMENT
+ STADIUM + SEED VAULT +
AMMO DUMP



NEIGHBOURHOOD CENTER

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[CPG]
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This exhibition is a collection of ideas proposing solutions to emergent need in the light of climate change. They are counterpoints to megacities with ecological footprints that are untenable. The continued depletion of natural resources leading to scarcity has resulted in displaced communities and will eventually lead to war.

What if we floated on sea instead of consuming land inefficiently?

And could we use wave energy instead of nuclear energy?

Could we replenish food supply and regenerate marine eco-diversity?

How would our lives be shaped by new offshore settlements?

What would we use as structures for shelter, farming scaffold and recreation?

Floating cities emerged in the 1960s with Buckminster Fuller's Triton City and Kenzo Tange's Tokyo Bay Plan. Current manifestations include Vincent Calebaut's Lilypad, the Seasteading Institute and the mile long Freedom Ship housing 50,000 people. These examples have huge raft-like surfaces which heat up the seawater and risk environmental damage. They minimize the opportunity of incorporating water bodies into interior urban spaces.

As an alternative to these examples, three types of vessels in the marine industry, viz the jackup platforms, the semi-submersibles and the super barges are re-purposed in seven projects to save the world.

Definitions

Semi-submersibles
When oil fields were first developed in offshore locations, drilling semi-submersibles were converted for use as combine drilling and production platforms. Whilst these vessels offered very stable and cost effective platforms, they can be explored as structures accommodating usages required of habitable work space.

As the oil industry progressed into deeper water and harsh environments, purpose-built production semi-submersible (SS) platforms were designed. During transit, an SS is de-ballasted to a draught where only part of the lower hull is submerged. During lifting operations, the vessel is ballasted down to keep the lower hull well submerged and to reduce the effect of waves and swell. High stability is achieved by placing the columns far apart to lift extremely high loads safely.

Of interest to the design of water spaces for floating settlements, the large sheltered space beneath the platform and between the hulls of the SS provide the opportunity for planners to imagine communal activities in a scale equivalent to a third of the urban space beneath the Eiffel Tower.

Semi-submersibles are particularly suited to a number of offshore support vessel roles because of their good stability, large deck areas and variable deck load (VDL). The high stability and VDL allows the possibility of built-up accommodation on to the platform. They are capable of operating in depths up to 3,000m and maintain their station in dynamic positioning mode. This offers great flexibility in the assembly and formation of a floating settlement as a flotilla of semi-submersibles.

Jack-ups
First built in 1954, jack-ups have become very popular in offshore applications up to 100m depth of water. Jack-up rigs rest on the sea floor and do not float. They are self-elevating and their legs are stationed on ocean floor whilst the drilling equipment is jacked up above the water's surface on a structural platform spanning three masted legs.

When their legs are not deployed, jack-ups float, which make these types of vessels easily transported from one drilling location to another. Some are capable of self-propulsion and do not need an outside source of movement. While towing is easily performed, barges are the transportation of choice when the jack-up needs to be moved quickly over a longer distance.

Jack-ups of over 100m height have open-truss legs which resemble electrical towers. The legs are made of tubular steel sections which have diagonal members to stiffen them. Jack-ups are supported by mats of 'A-shaped' like, connected to the bottom of each leg of the jack-up, ensuring that the rig does not punch through the ocean's bottom. Once the jack-up is on location the legs are lowered to the ocean's floor and the rig platform elevated well above the water's surface. Hydraulic cylinders equipped with moving and stationary pins extend and retract to climb along the legs of the jack-up.

Jack-ups are particulary versatile in varying their platform height to accommodate different depths of water. For the architect, this translates to variable heights in the communal space between the legs of the jack-up. Between 20-40m depth of water with 180m tall mast, a jack-up has a giant shaded water body about 35-55m (height above water level) undercroft equivalent to three-fifths of the urban space beneath the Eiffel Tower. This leaves 100-120m high by 3500m^2 of buildable air space which can accommodate 600 housing units varying in size from 64-128m^2.

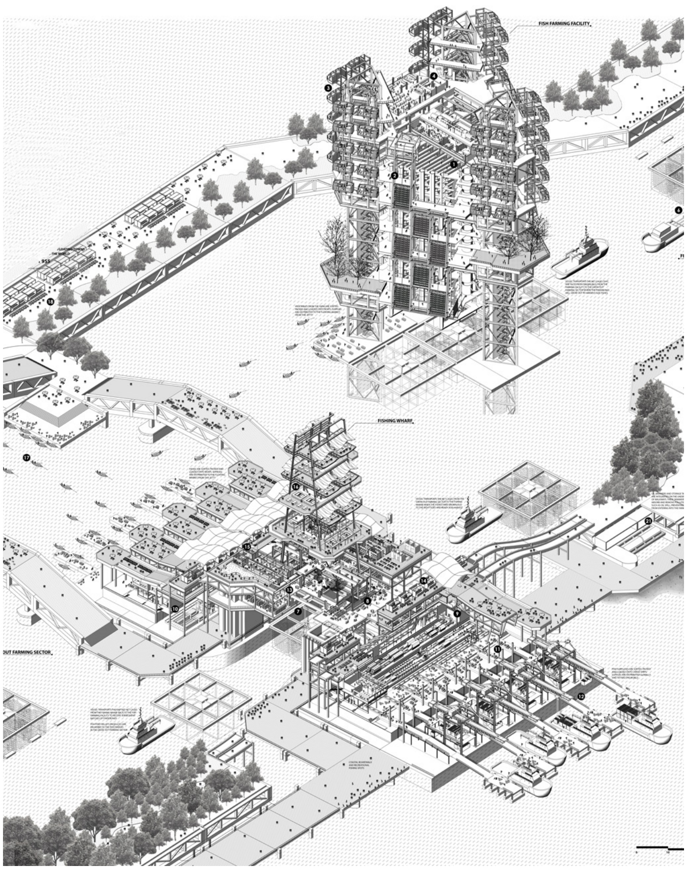
Jackups and semi-submersibles have very low footprints compared to large scale floating rafts. Thus, they have a minimum environmental impact on the sea water.

What if we were to integrate vegetable farms with fish farms?

Food supply is increasingly threatened by over-fishing whilst fish farms can cause pollution to coastal environments. This jack-up rig with on board worker accommodation (in capsules) and waste treatment facilities is configured to replenish global supply of fish and for export consumption.

Aquaponics systems are integrated into the vertical faces of the rigs whilst growth tanks from fingerling stages are housed in three main platforms. The top platform is dedicated for an elevated al fresco experience and the undercroft of the rig allows workers to feed the adult fish in growth nets immersed in seawater.

Nets of mature fish are towed from the farm between the legs of the semi-submersible to be processed into a wholesale market and a fishing port. The tower derrick is used to support elevated dining terraces with dramatic views of the sea.The wholesale market and seafood eateries are positioned above the preparation/packing and distribution facilities below, which lead to the wharfs. This is a major node located at the edge of a water settlement.



Jack-up Fish Farm

Davis Wong

Rig type	3-legged jackup
No. of workers No. of workers dormitory	120 60 [28m² each)
Types of growth chamber [12,900m² total growth area]	4 types: broodstock, hatchery, pre-nursery and nursery
Seawater bodies [1,298,700m² total water area]	80 net cages in open seawater [1,285,800m² of water area]
Fish production yield	33,600 tonnes/year can feed 1,680 people
Vegetable production yield	100 tonnes/year [workers consume 12 tonnes/year, 88 tonnes/year for export]
Energy source	Wave harnessing generators at 380 million kWh/year [48 million kWh is required to operate the JU fish farm]

Surplus fish to feed world population

In 2017	In 2025
7.4 billion people consume 148 million tonnes	8.1 billion people consume 162 million tonnes
4,400 JU fish farms required to meet demand	4,820 JU fish farms required to meet demand

Savings in land area
[based on Singapore - 5.34km² of land+water area produces 5,200 tonnes of fishes per year]

In 2017	In 2025
152,000km² of land+water area required	166,000km² of land+water area required
4,400 JUs [5,700km² of water area]	4,820 JUs [6,200km² of water area; takes up 0.002% of earth ocean surface]

Semi-submersible Fish Wharf

Rig type: Semi-submersible

Schedule of accommodation
- Harvesting
- Unloading and sorting bay
- Processing facility
- Waste to fish feed production plant
- Packing, sorting and distribution port
- Cold room storage
- Office workspace
- Wholesale market
- Sky dining and restaurants

Fish distributed in a year: 33,600 tonnes

Area comparison

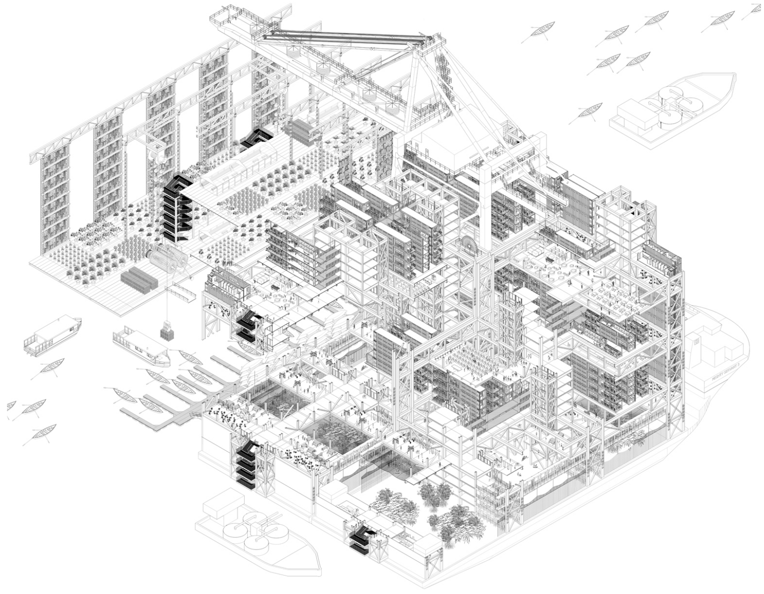
Senoko Fishery Port	Jurong Fishery Port	SS Fish Wharf
32,400m²	51,000m²	33,300m²

Proposed semi-submersible fish wharf is comparable to Senoko Fishery Port, but with the advantage of an integrated processing facility and public recreation spaces, not currently availabe in existing fishery ports.

Post-disaster housing is fraught with delays in organization, dubious build quality and the absence of sanitary infrastructure and water supply.

How would a superbarge fitted with cranes sail to location and set up a settlement in one week with container box accommodation including on-board waste water treatment facilities and aquaponics infrastructure to jump-start self-reliant economy based on vegetable and water production?

Could the same superbarge be reconfigured into a floating campus facility complete with performance set-ups, learning spaces ,dormitory and sea sports recreation ?



Superbarge Settlement

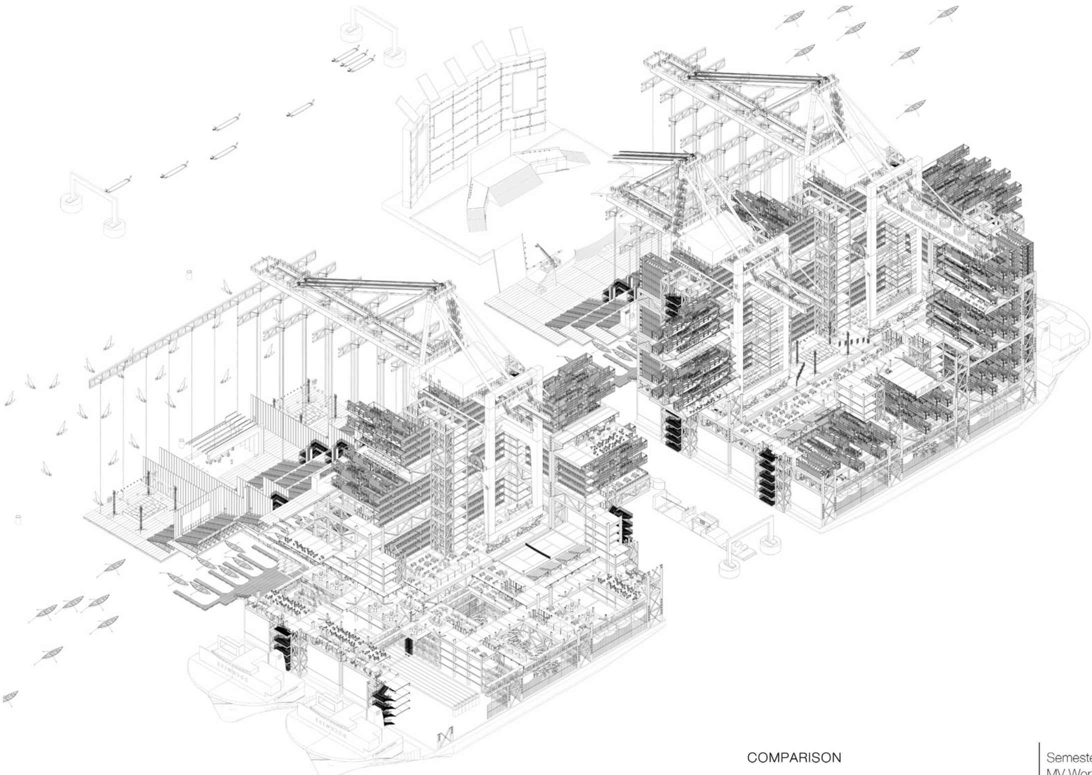
Sakinah Halim

Vessel type	Two superbarge modules
Structural additions	• Two panamax ship-to-shore gantry canes • Steel frame structure to support container stacks
Total settlement area	12,000m^2
No. of people per superbarge module	5,184
No. of days to assemble each module	Cargo arrives at disaster site in 7 days and assembled within 48 hours
No. of containers	624 x 40 ft containers [housing,bathroom] 648 DNV crash container frames [verandahs, corridors]
No. of people per housing unit	12
Total bathroom area	2,880m^2
Cooking and food preparation	432m^2
Dining area	432m^2
Farming yield capacity	575 tonnes/year [6,393m^2]
Learning spaces	594m^2
Play and recreational area	1,296m^2

Area comparison

	Hagadera refugee camp (largest in the world)	Superbarge settlement
Footprint (m^2/person)	81.3	1.45
No. of people	106,926	549,504 [106 modules]
Per housing unit	10m^2 per 8 people	30m^2 per 12 people

No. of superbarges needed for future projection?	106 [to accommodate 549,504 displaced people in a disaster of the scale as 2008 Aceh tsunami (4th largest in the world)]
Energy source	LNG from cremation barges
Waste type and treatment strategies	<u>per superbarge module</u> 477,358m^3 wastewater per year treated at three WWT SSAUs [treating capacity of 69 million m^3 wastewater per year]
Water supply	42 million m^3 potable and non-potable water produced by three WWT SSAUs <u>per superbarge module</u> consumes 285,716m^3 water per day



Superbarge Campus

Vessel type	Two superbarge modules	Communal and study spaces	$864m^2$
Structural additions	• Two panamax ship-to-shore gantry cranes • Steel frame structure to support container stacks	Auditoriums and lecture theatres	$6{,}393m^2$ for 600 students
		Seminar rooms	$648m^2$ [$108m^2$/room for 45 students]
		Dance studios	$648m^2$ [$108m^2$/room for 2-40 students]
		Sea sports facilities	
		Olympic-sized swimming and diving pool	$864m^2$
No. of students per dormitory	6 [$30m^2$]		
Residents only dining hall	$1{,}296m^2$	No. of water polo pools	2 [$864m^2$]
Common dining hall	$432m^2$	No. of racquet courts	2 [$432m^2$]
		Outdoor sports facilities	
		Ninja warrior training course	$5{,}000m^2$
		Sailing, dragonboat, kayaking spaces and outdoor performances	$29{,}000m^2$ [can accommodate approx. 3 x $9{,}960m^2$ Marina Bay Floating platform stage]

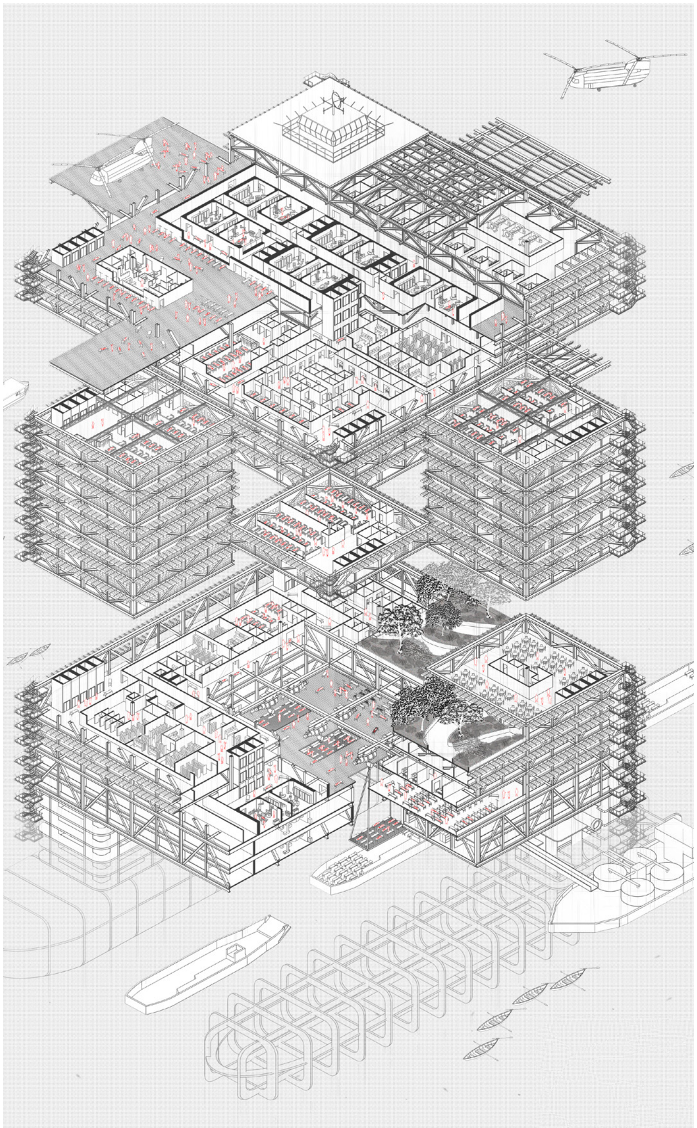
COMPARISON		Semester at Sea on MV World Odyssey cruise ship	UTown residential colleges, education resource centre & Stephen Riady centre	Superbarge campus (per module)
Total footprint (m^2)		4,025	190,000	12,000
Capacity (pax)		773 cabin + crew	4,100 undergraduates, graduates, faculty staff	4,896
Learning facilities	Auditoriums (no. x capacity)	1 x 600 pax	2 x 470 pax each	3 x 600 pax each
	Lecture theatres (no. x capacity)	-	4 x 150 pax each 1 x 200 pax	6 x 200 pax (reconfigured from auditoriums)
	Classrooms / Seminar rooms (no x capacity)	9 x 80 pax each	9 x 25 pax each	6 x 45 pax each
Performing Arts facilities	Dance studios (no x capacity)	-	3 x 2-20 pax each	6 x 2-40 pax each
	Practice rooms (no x pax capacity)	-	10 x 2-120 pax each	-
Sports and recreation areas	Sports hall	1 fitness center and sauna	2 multipurpose sports hall 1 gym 1 rock climbing wall	2 racquet courts 1 ninja warrior training course
	Pool (no)	1 recreational pool	1 recreational pool	1 olympic size pool, 1 diving pool 2 water polo pools
Outdoor green/ blue areas (m^2)		-	$4{,}500\ m^2$ Town Green	$29{,}000\ m^2$ open water recreational / performance area

If we were to sail a hospital to a disaster stricken coastline in 35 hours stipulated by the United Nations rescue services, how would we receive many casualties by air-lift and hovercraft?

How would we maximize X-Ray rooms, ICUs when triages need to be outsized?

How would we treat toxic waste and layout wards to prevent cross-infection?

What would power this offshore facility?



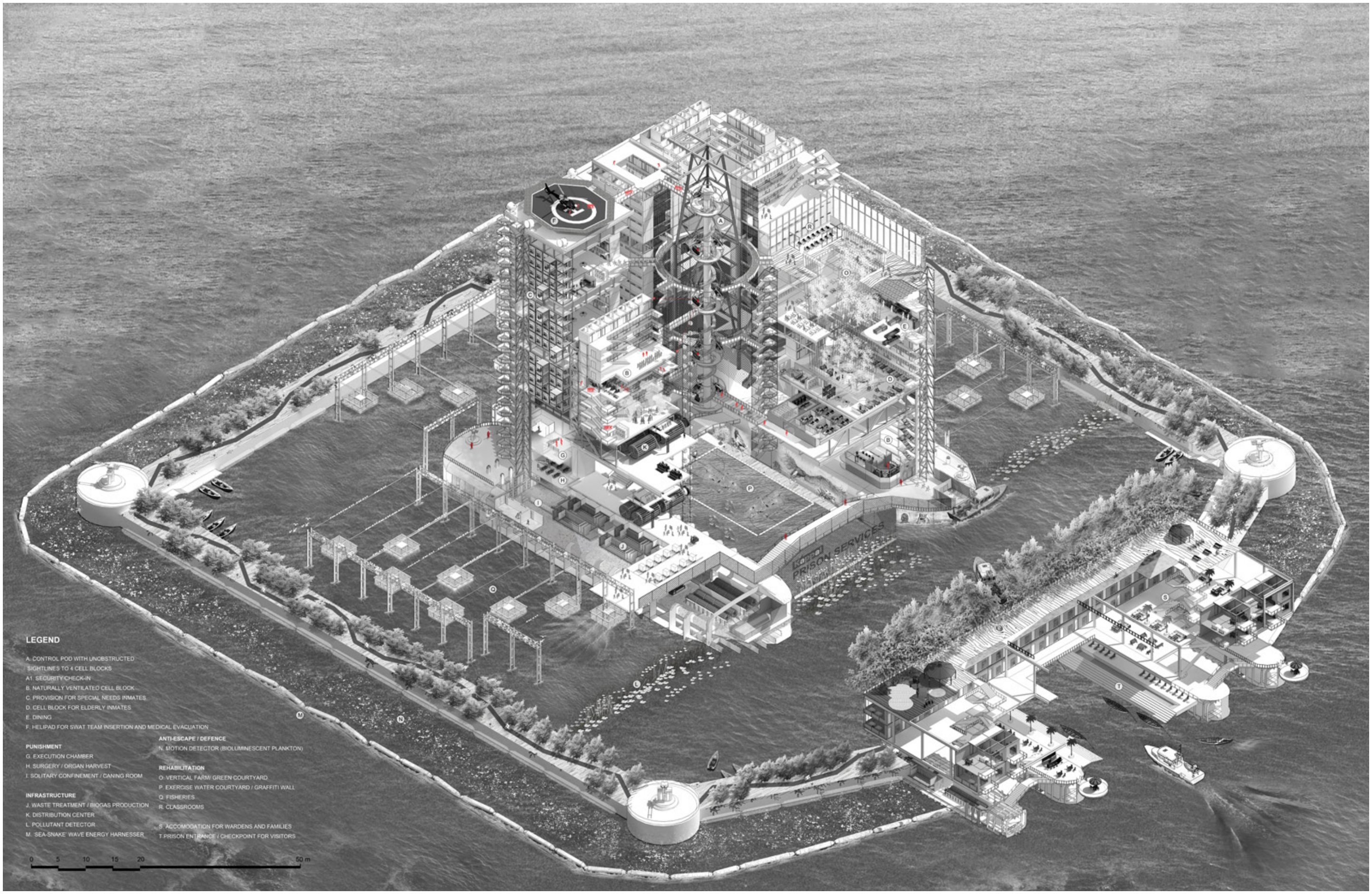
Semi-submersible Hospital | Bek Tai Keng

Rig type	Semi-submersible
No. of chinook helipads	4
No. of landing craft unit	3
No. of incoming rescued persons in one landing	96 by air 210 by sea
Area of each triage	3,363m² for air rescue 1,425m² for sea rescue
No. of ward beds [19,960m² total area]	1,424 beds [28 wards]
No. of ICUs	144 [3,153m²]
No. X-ray rooms	18 [841m²]
No. of surgical rooms	23 [3,452m²]
No. of recovery beds	98 [1,288m²]
Medical crew accommodation	3,465m² can house 400 crews
Canteen	1,426m²
Central kitchen	1,237m²
Recreational facilities	1,426m²

Area comparison

Red Cross field hospital	Medecins Sans Frontieres inflatable hospital	SS Hospital
32,400m²	14,000m²	6,162m²

Waste type and treatment strategies	Hospital waste sent to mobile crematorium for incineration Wastewater sent to treatment plant
No. of rigs needed for world population?	8,810 [provision guideline: 2 beds per 1000 persons 1680 beds per SS hospital can support 840,000 people 14,800,000 beds or 8,810 SS hospitals can support 7.4 billion people]



Semi-submersible Prison

Christopher Wijatno

Rig type	Semi-submersible	
Comparison	Changi prison	SS prison
Footprint	$11{,}972m^2$	$11{,}660m^2$
No. of cells	768	1600
No. of officers	128	133
No. of prisons to house 48 million inmates in 2050? [world population x average incarceration rate*] *ref: http://www.prisonstudies.org/highest-to-lowest/prison-population-total	62,500 Changi prisons [9.6 billion x 0.005 / 768]	30,000 SS prisons [9.6 billion x 0.005 / 1600]
Footprint in 2050	$748{,}250{,}000m^2$ (land area that can be saved) [62,500 x $11{,}972m^2$]	$349{,}800{,}000m^2$ [30,000 x $11{,}660m^2$]

Vegetable farming	843 tonnes
Fish farming	45 tonnes
Exercise yard	$15{,}700m^2$
Dining hall	$380m^2$
Sick bay	$325m^2$
Warden housing	$8{,}200m^2$
Hanging chamber	$100m^2$
Energy source	wave energy, biofuel, piezo electricity
Waste reclamation capability	2,987kg compost per day

The costs of incarceration to the state in feeding prisoners is compounded by global supply shortage of wardens and severe overcrowding.

What is the cell capacity of a semi-submersible that can feed all its inmates with aquaponics and fish from the sea and run on wave generated electrical power?

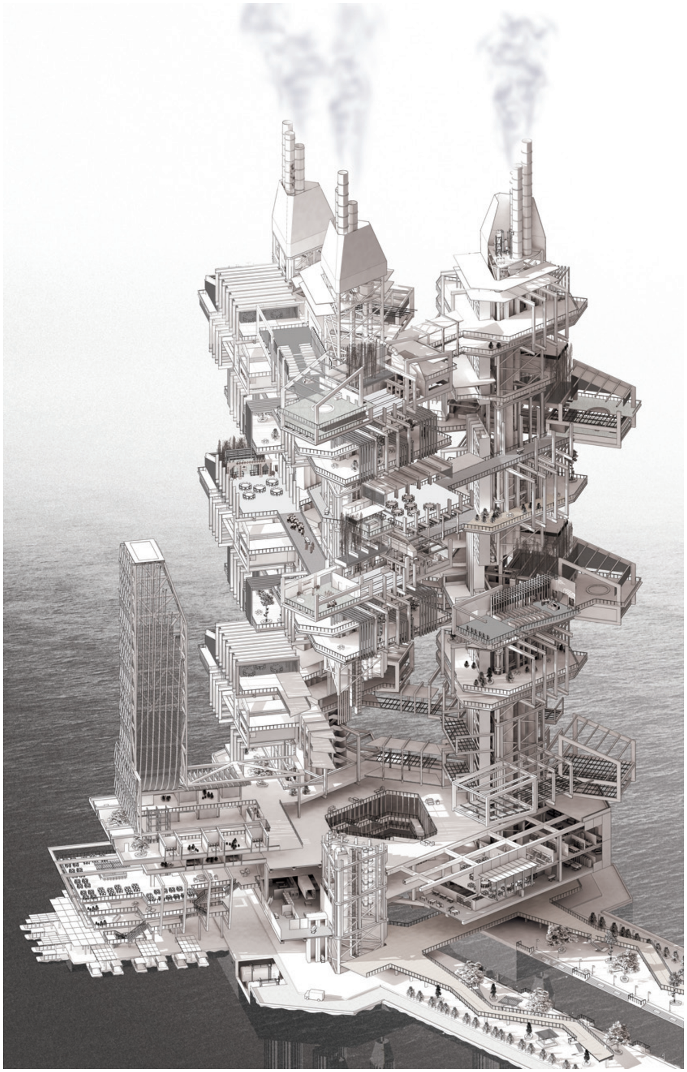
How would the layout incorporate warden accommodation and optimize staffing limitations?

How many such floating prisons would be needed to accommodate the projected global figure of inmates in 2050? And how much land would have been saved?

The projected mortality rate of growing populations imply a scarcity of land for future burial. Cremation locations require buffers from city space and affect land usage. The separation of spaces used for wakes, last rites cremation and columbaria generate traffic between different locations.

What if we were to create only one location for all purposes?

This jack-up rig accommodates all funerary processes viz wake halls, last rites, cremation witnessing, reception, ash collection including a jetty for boats to cast away ashes in the sea.



Jack-up Funerary Facility

Wang Yigeng

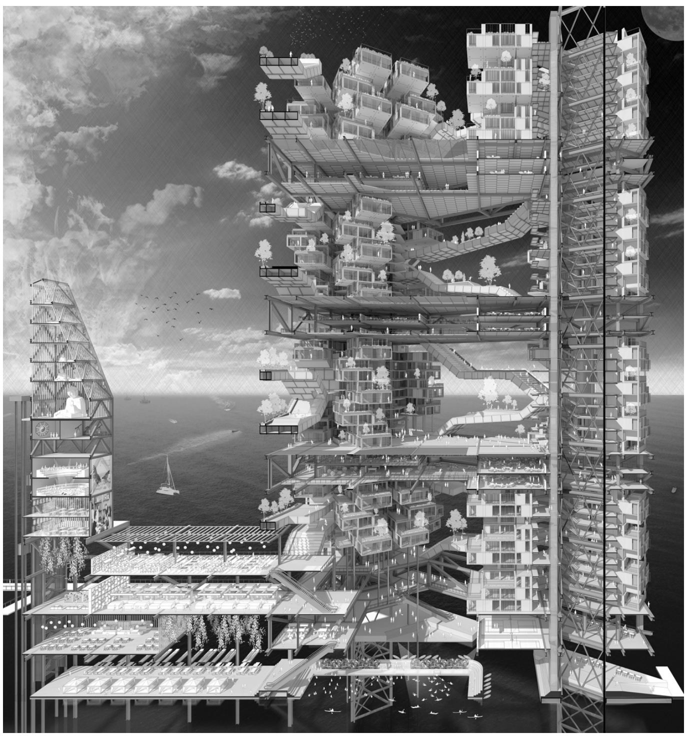
Rig type	3-legged jackup	Energy source	LNG
No. of wake halls	9		
No. of service halls	9		
No. of reception garden decks	18	Waste reclamation capability	126 tonnes/year of ash compost which can grow 61,300 trees/year or 12,678 tonnes/year of tomato fruit or 40MWh electricity daily
No. of cremators	27		
Area of public rituals	2,000m²		
No. of rigs to accommodate world cremation figure in 2050?	2,165 [10% of land-based footprint]		

Land forms of housing are limited by the extent of private and shared communal open space and frontage opportunities for apartment view.

If a jack-up platform were moored at 30m depth of water, how many housing units would be accommodated in the remaining 100m height of its masts?
All with a private terrace and a view to the sea and a proportion of sky gardens that exceeds that of the Pinnacle at Duxton?

More importantly, how would this change the structure of housing precincts and neighborhoods if school, recreational, market, worship and workspace facilities were integrated into one structure accessed by water void decks where residents commuted by boat or water taxis?

How many such jack-ups would be needed to house 7 billion people in 2050 and what would be the patch of water occupied by entire settlements compared to the land required to house the equivalent township?



Jack-up Housing

Chen Qisen

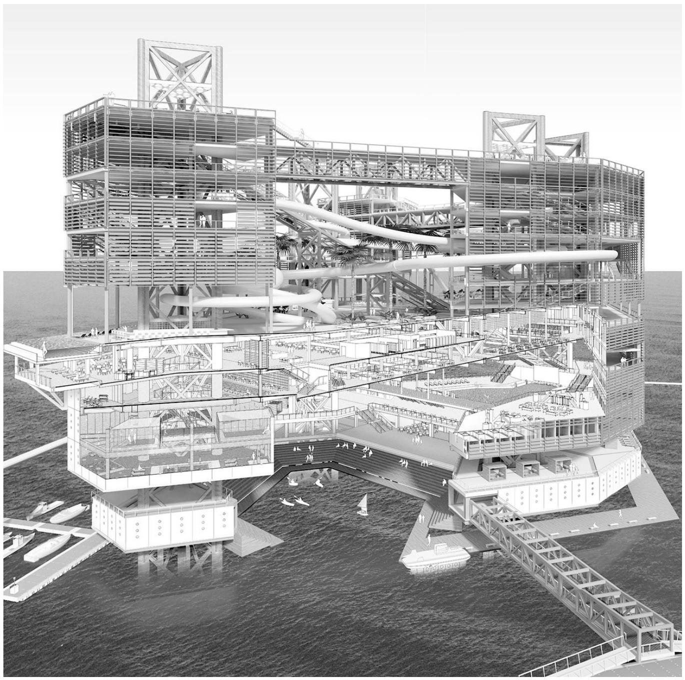
Rig type	3-legged jackup	Total energy required	2,907,736kWh/year [domestic usage] 1,109,600kWh/year [machinery and service]
No. of apartments	672		
No. of residents	3,360		
Apartment sizes	64, 96, 128m^2		
Total apartment area	64,512m^2		
No. of private sky terraces	672 [21,504m^2]	Household foodwaste	467kg/day average
No. of public sky gardens	12 [12,000m^2]	Biogas container	2 x 20 ft containers operates on 380w
No. of rigs to house population figure in 2050?	2,083,340 rigs to house 7 billion people or 28,000 settlements [38.5km^2 per 250,000 people]	Electricity for battery storage (microgrid)	11,000kWh/day
Potable water	650 tonnes [domestic usage] 800 tonnes [output]	Battery storage container	4 x 20 ft containers, one on each hull
Desalination containerized plant	2 x 40 ft containers on the bottom hull [consume 277,250kWh/year]	Foodwaste to biogas energy	563,997kWh/year
Greywater	130 tonnes [irrigation] 150 tonnes [output]	PV panels on roof (solar radiation x effective PV area)	6,896MW/year [1,667kWh/m^2 x 4,137m^2]
Sewage treatment containerized plant	6 x 40 ft containers on the top hull [consume 831,750kWh/year]	Electricity generated from PV	1,531,000kWh/year [22.2% of 6,896MW]
		Total energy generated (PV + biogas energy)	2,094,997kWh/year [meets 50% of energy requirement]

Why do many water theme parks run out of money?

Water theme parks consume an inordinate amount of water and energy for pumping and filtration and virgin land. High daily costs make them vulnerable to fluctuations in patronage and there is much wastage in investment costs including land.

What is a design for resiliency?

Comprising two jack-up rigs, this water park uses wave energy and produces surplus water after-treatment. Water slides are configured to minimize the height to which water is pumped and intertwined to maximize run-length on the rig platforms.



Jack-up Water Park

Roy Tay

Rig type	3-legged jackup
Length of water slide	480m
No. of restaurant	1
No. of cafes	3
No. of bars	2
No. of short-stay cabins	40
Land saved	> 4hA
Volume of surplus freshwater	200m^3/day
Freshwater usage in washroom	120m^3 per 2000 visitors

Pool volume (filtered seawater)

Tornado and Behemoth bowl landing pools	67m^3 [6.1m x 12.2m x 0.9m depth]
Serpentine rides landing pool	29m^3 [7.6m x 12.8m x 0.3m]
Wave pool	2,500m^3

Energy source OTEC (10MW)

Pros

- Discharged cold seawater is passed through a heat exchanger to chill the freshwater in a closed circuit, which is subsequently used to cool spaces
- The surface seawater evaporated to drive the turbine in an OTEC plant, sheds its load of sea salt. Termed as *ocean mining*, the salt retrieved from the evaporation chamber can be sold as a product in its raw form or further refined to extract metals and trace elements.

[ref:www.makai.com/ocean-thermal-energy-conversion/]

Cons

- The energy consumption of an OTEC cycle is dominated by the seawater pumps. These pumps and other auxillary equipment consume 20% of the total electricity produced.

In an age of unsustainable practices and climate change, the idea of survival is not tenable in countries where governments lack resources or political will to provide infrastructure and food security as a basic human right. Meanwhile the ongoing plight of climate and economic refugees displaced by natural disasters and political strife is ignored in mainstream research on smart technologies in future cities.

The idea of alternative floating settlements to empower under four thousand people in upscaled boat communities is explored in this design inquiry.

How would such communities grow food, provide dwelling, learning and recreational activities on board floating entities with rain and salt water?

What if large barges were converted to crop production and distribution to replace the farmplot with a barge farm integrating farmhouse accommodation, and granary?

What would be their yield capacities and input resources be?

How many people could be permanently resident on board a barge whilst facilitating learning and recreation with low energy and waste loop systems to minimize effluent into seawater and regenerate marine ecologies?

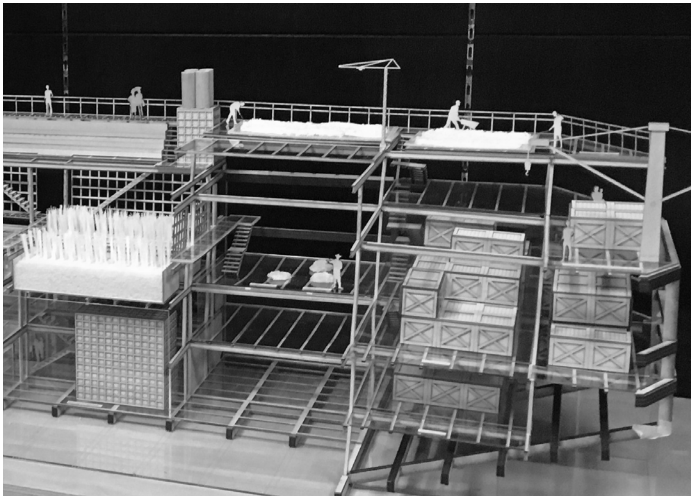
Two 90m long barges were conceived in this experiment, one as a farm barge and another as a generic proposition for residential learning, and recreational purposes

Barge Farm

Karen Ho

Vessel type	One barge module
Farm Deck	
Sorghum plot size	• 10 plots x 22m^2 • 5 plots x 42m^2
Monthly yield	24 tonnes/hA
Seasonal yield	1,032 tonnes/four months
Yearly yied	3,096 tonnes
Average yield	258kg/month
Cotton Planting	26m^2
Drying façade	
Usable	206m^2
Decorative	150m^2
Water tanks	
Freshwater (for farming)	120m^3
Freshwater (for residential)	30m^3

Bow	
Sorghum bar	230m^2
Brewery	165m^2
Top deck	230m^2
Hull	
Restaurant (including billiards)	278m^2
Storage (seeds, nutrients and fertilizer)	412m^2
Living quarters	425m^2/88 people
Shower and WC facilities	48m^2
Stern	
Sorghum factory processing	188m^2 (winnowing) 70m^2 (drying)
Packing and cargo storage	395m^2
Loading and unloading bay	200m^2

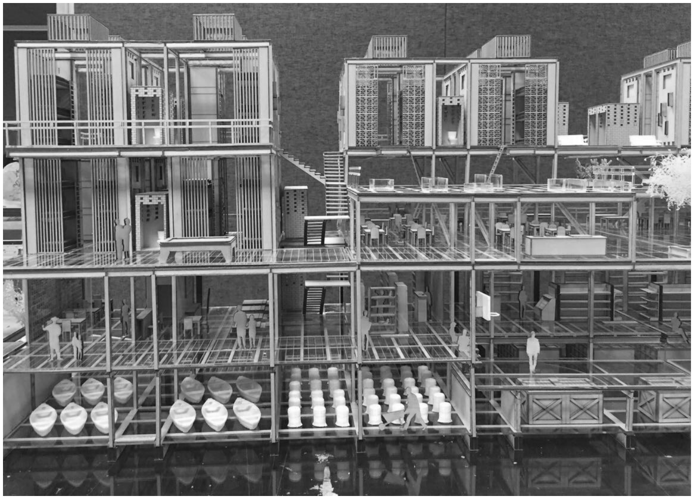


Barge Dormitory

Zhang Linwang

Vessel type	One barge module
Dormitory	
No. of blocks	8 to house 400 persons
No. of beds naturally ventilated	288
Shower and WC facilities	56m^2
Footprint (m^2/person)	37m^2

Top hull deck	
Garden/ orchard	453m^2
Bow	
Pilot control room	34.5m^2
Trellis courtyard	114m^2
Hull	
Dining	853m^2
Recreation	139m^2
Basketball court	143m^2
Meeting room	33m^2
Water tank	250m^3
Canoe storage	240 canoes
Water/ food/ cargo storage	306m^2
Stern	
Outdoor performance stage	144m^2
Engine room	20.8m^2



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