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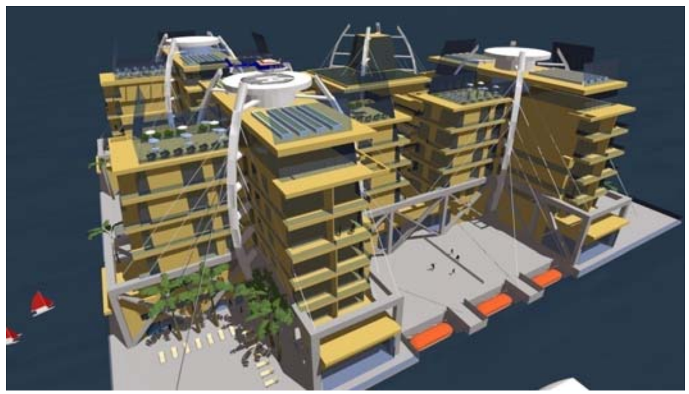
Feasibility and Design of the ClubStead: A Cable-stayed Floating Structure for Offshore Dwellings



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Marine Innovation and Technology
Patri Friedman, Wayne Gramlich
The Seasteading Institute

Objective

Propose a **floating** design adapted for **long-term and autonomous living for** small communities

(~ 300 people)

in the **open-ocean** (>200 miles from the coast)

⇨ Passenger comfort:

maximize space

motion control

⇨ Structural reliability / Seakeeping

minimize footprint

stability

⇨ Cost optimization: *minimize displacement*

Motivation and Background

- Known experiences of offshore settlements:
  - Principality of Sealand on a former WWII British sea fort
  - Conversion of cruise ships
- Recent research:
  - MegaFloat in Japan (see Kikutake (OMAE 1998) and Kobayashi et al. (OMAE 1998))
  - Generally, developments of pontoon-type Very Large Floating Structures (VLFS) reviewed by Watanabe et al. (2004)

Clubstead Project

Design Concept

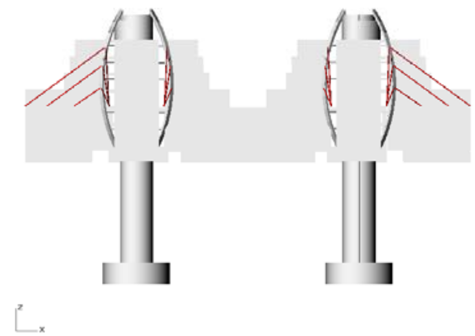
Architectural Program

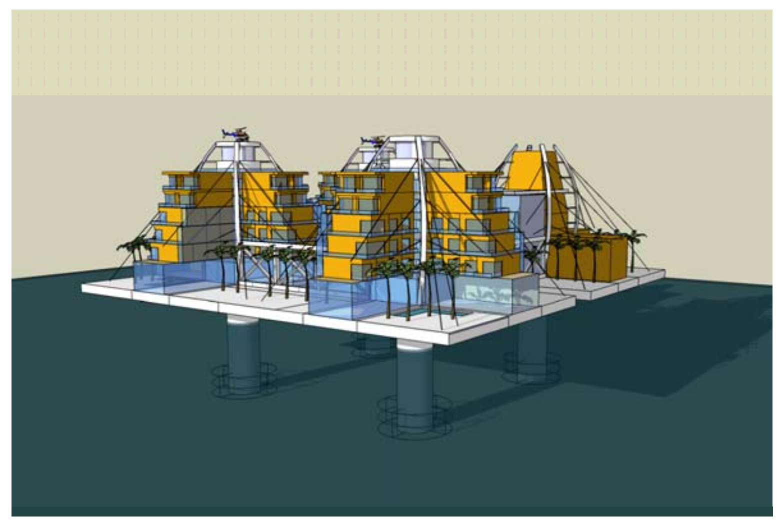
Structural Engineering

Rigid-Body Response

Design Proposal: a novel concept

Initial Idea





OMAE 2010 – Shanghai, China

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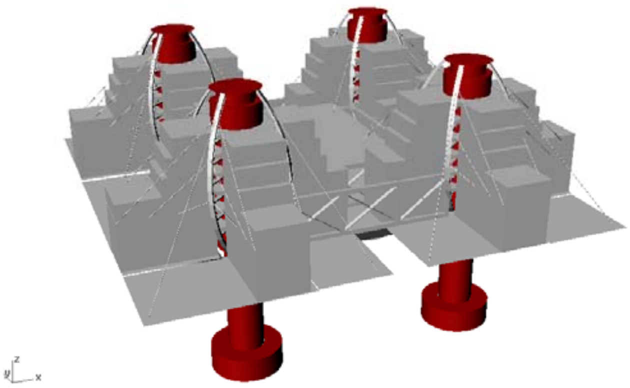
Design Proposal: a novel concept

A Column-Stabilized Design

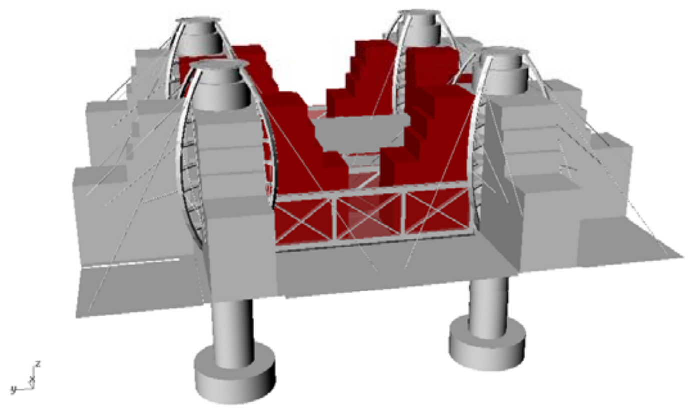
4 columns with large footing:

- Minimized Displacement
- Enhanced stability
- Additional damping and added mass from footing
- Motion control



Design Proposal: a novel concept

Trusses and Cable Stays

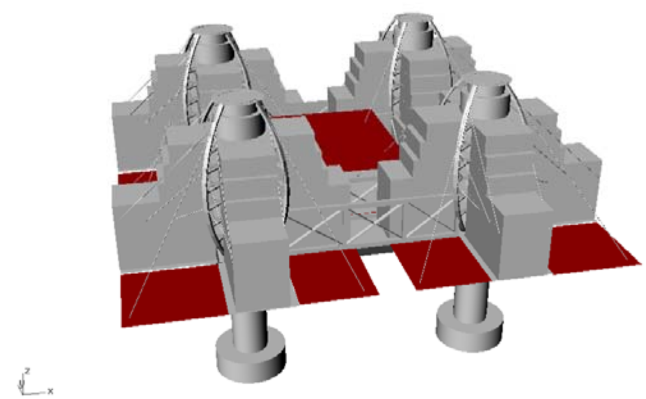


To support wave loads and heavy weight

- Truss between columns
- Cantilevered truss

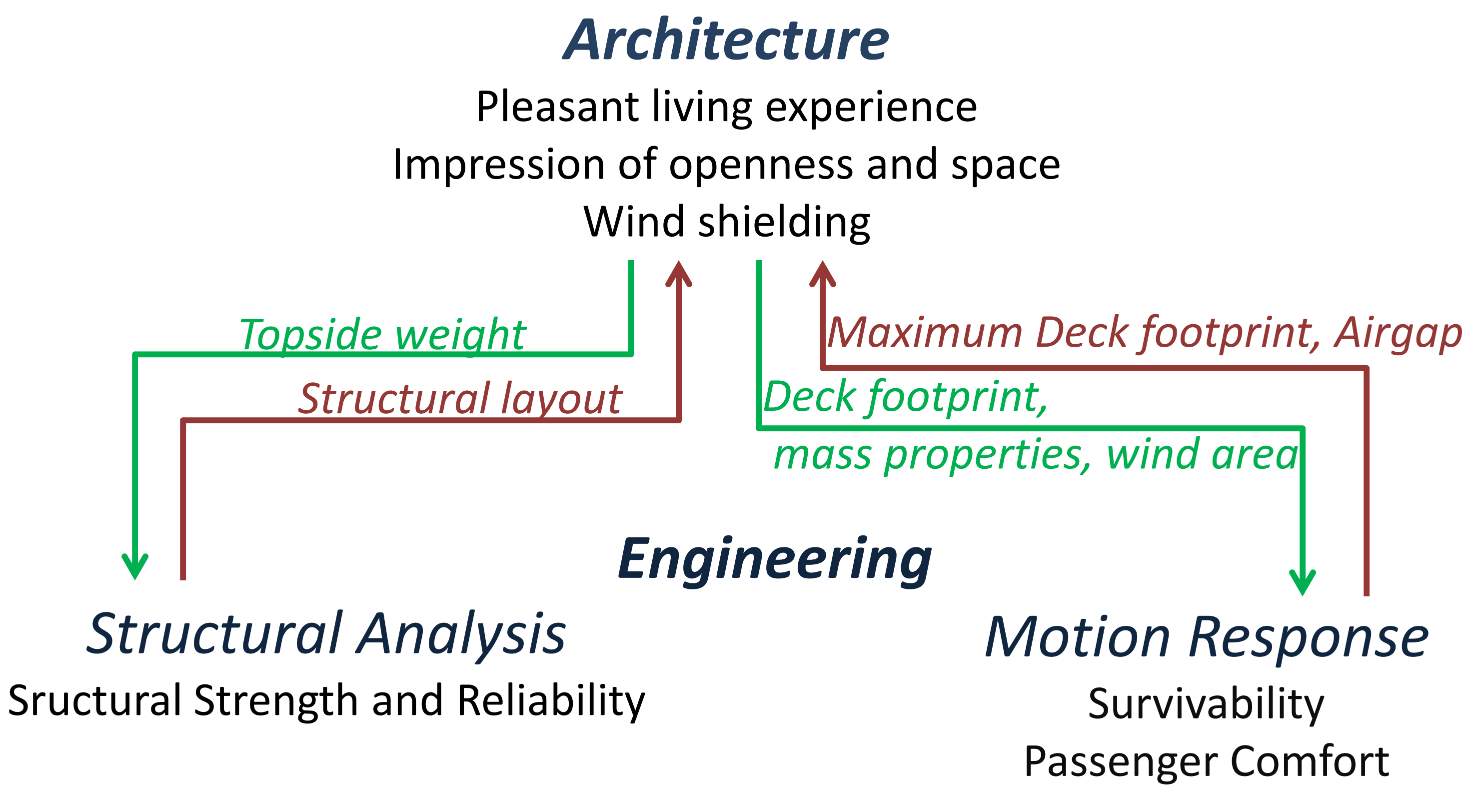
To support light areas:

- Cable stays



Design Approach

Iterations between the architectural aspect and the engineering aspect of design:



Clubstead Project

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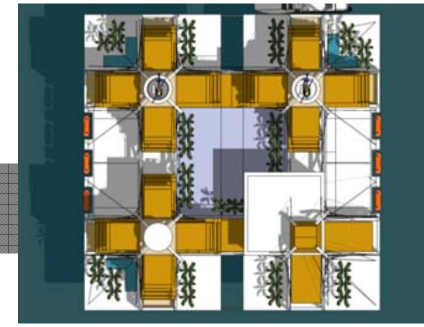
The Architectural Program



Incorporating Engineering Features

Stay Cables   Tower   Curved Beams   Truss

The architecture

- Incorporates engineering features
- Is driven by structural layout

Buildings supported by truss

Gardens and outdoor spaces supported by stay cables

The Architectural Program

Incorporating Engineering Features

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The Architectural Program

Incorporating Engineering Features

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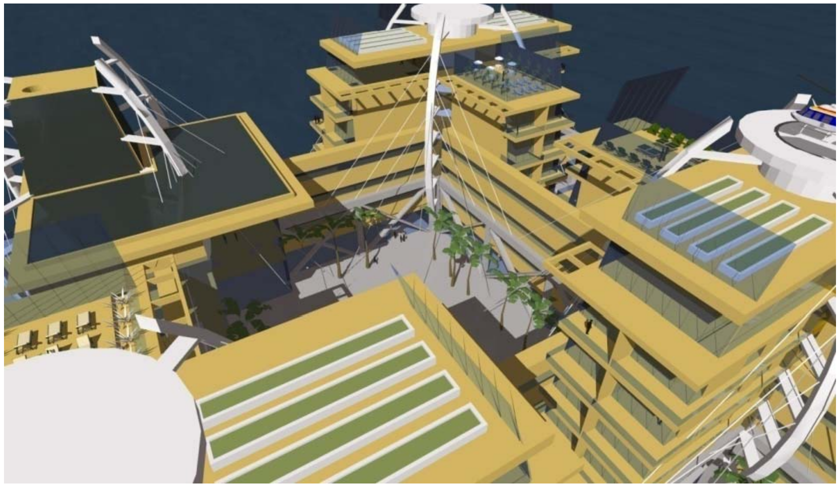
The Architectural Program

Optimizing the Living Spaces

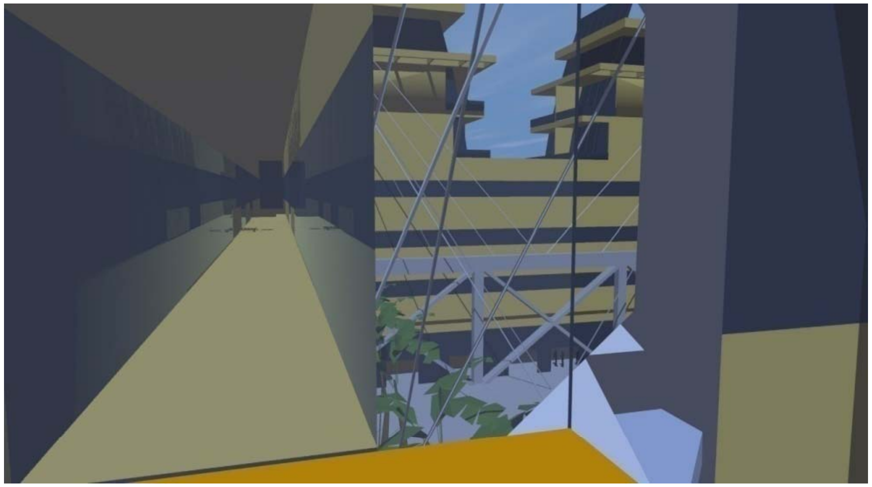


To maximize the use of available space:

- Roof-tops gardens
- Terraces and balconies

To convey an impression of space:

- Use of glass
- Use of light
- Architectural shaping and slenderness of the buildings



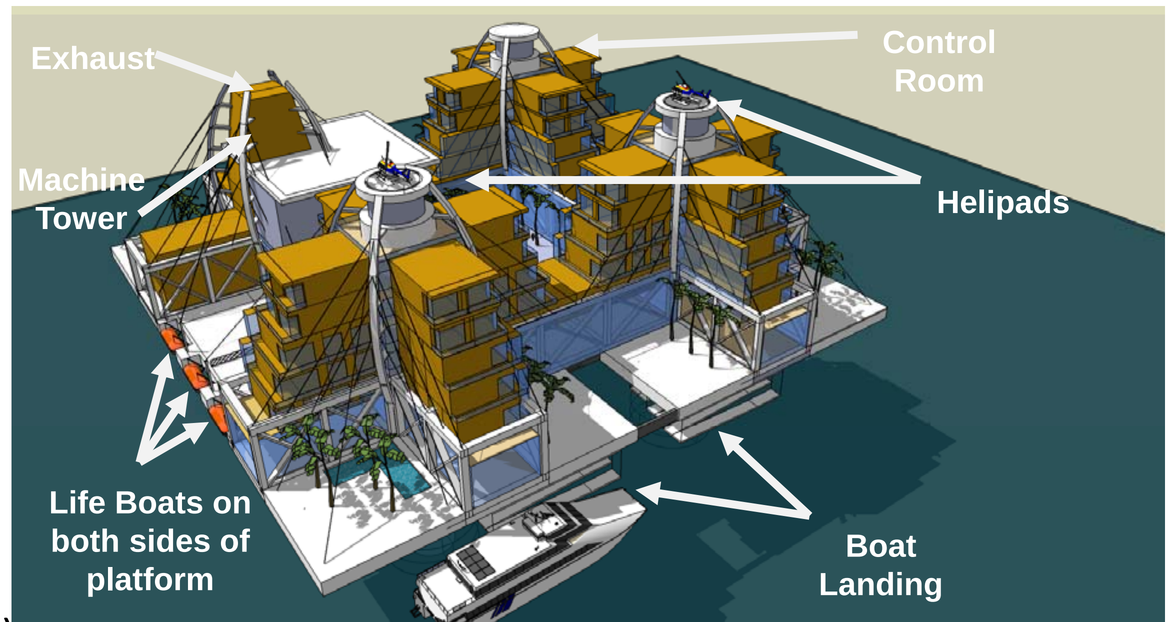
The Architectural Program

Accommodating the Necessities of Ocean-Life: Daily needs, SOLAS

Medical Emergency
- Medical treatment center
- Helipad and helicopter for emergency medical evacuation

Fire Safety
- Fully equipped fire-fighting station
- Equipped sub-stations
- Fire insulation and prevention
- Trained staff

Emergency Evacuation
- Life jackets
- Evacuation plan
- Rescue boats and self-inflating life rafts
(for 2x number of passengers)



Communications
- Safety Center with communication system
- Emergency signals (visual / radio)
- Radar

Clubstead Project

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Structural Reliability

Structural Analysis

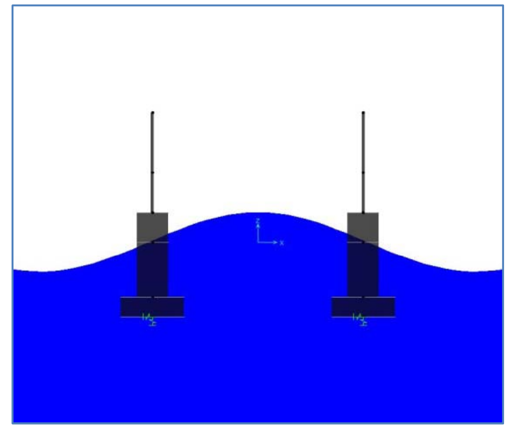
Design Criteria:

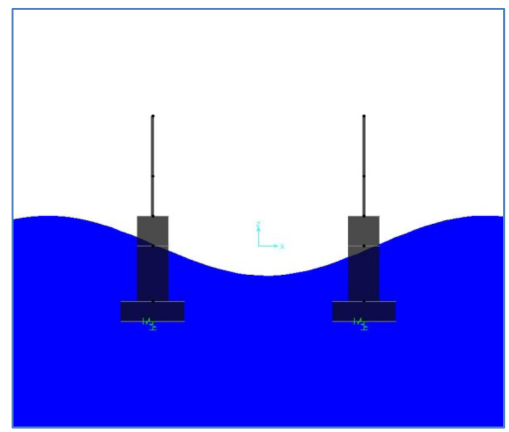
- Truss: API buckling verification for tubular members
- Cables: Maximum tension
- Tower: column buckling check

Design Sea-State:

Linear Airy Wave H=35 to 45 ft

Squeezing, prying modes





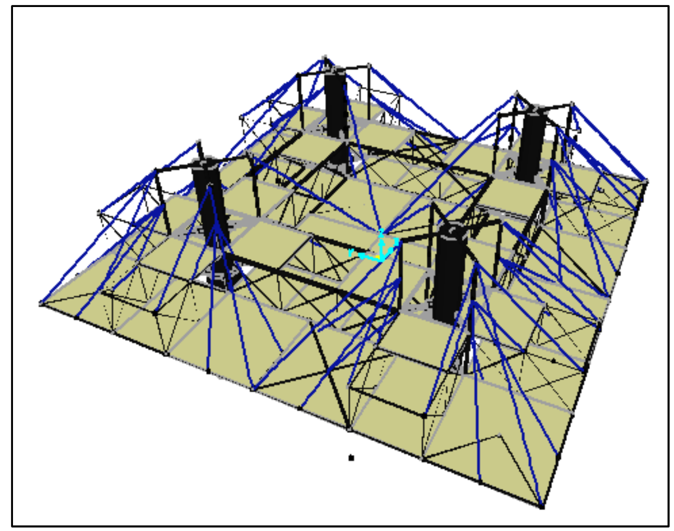
Structural Reliability

Structural Analysis

Finite Element Model:

- Software SAP2000 v11, with optimization feature
- Beam theory for truss design and towers
- Cable elements for stay cables with static tension

Total weight of deck structural support = 2,351 s.t.



Clubstead Project

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Rigid-Body Response

Understanding the Environmental Conditions

METOCEAN

- Wind & wave data obtained from NOAA buoy
- Statistics:
  - Extreme sea-states

Return Period		1 year	10 year	100 year
Hs	*m*	7.0	7.7	8.3
Tp	*s*	14.3	14.3	14.3
Wind Speed	*m/s*	16.0	17.5	18.9
Current Speed	*m/s*	0.48	0.53	0.57

  - Operational sea-states in wave scatter diagram

Surviving a storm in the open ocean

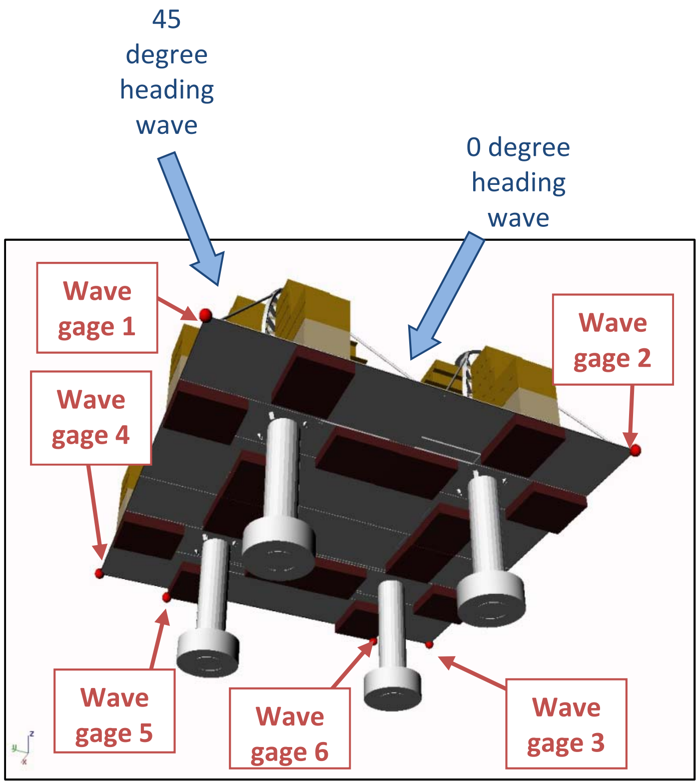
Hydrodynamic Analysis in Extreme Sea-States

Survivability criteria:

- Low pitch response
- Deck areas above wave crest

Methodology:

- 3 hour simulations
- TimeFloat 6DOF time domain program



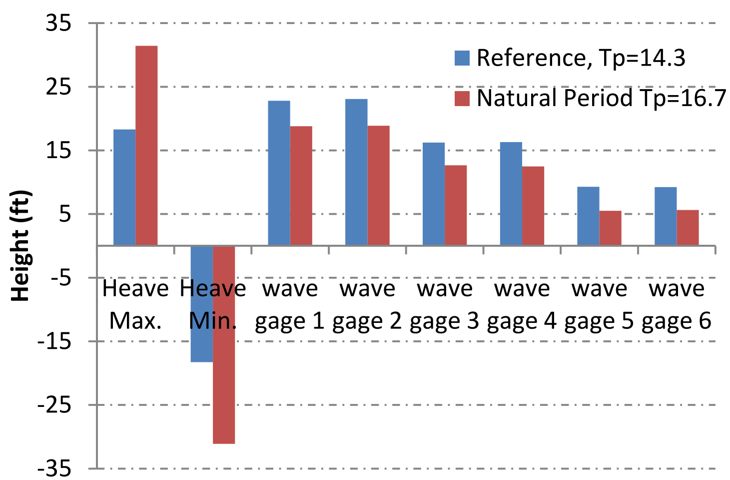
Surviving a storm in the open ocean

Hydrodynamic Analysis in Extreme Sea-States

- Maximum Pitch = 5.45°
- Minimum Clearance at Wave Gauges = 5.83ft

Survivability Criteria are met off San Diego with Hs = 8.3m

100 year - 0 deg		Mean	RMS	Max	Min
Wave	height	0.11	6.79	27.34	-28.96
Motions	surge	48.36	5.73	76.18	32.36
	sway	0.42	0.05	0.69	0.30
	heave	-0.01	6.42	19.56	-19.86
	roll	-0.03	0.05	0.13	-0.20
	pitch	1.76	0.97	5.45	-3.10
	yaw	-0.56	0.10	-0.26	-0.98
Wave Gauges	1	53.19	8.47	85.31	22.79
	2	52.97	8.44	85.56	23.07
	3	40.97	7.55	64.86	13.70
	4	40.75	7.57	65.30	12.65
	5	33.79	7.56	58.17	5.83
	6	33.93	7.55	57.90	6.49



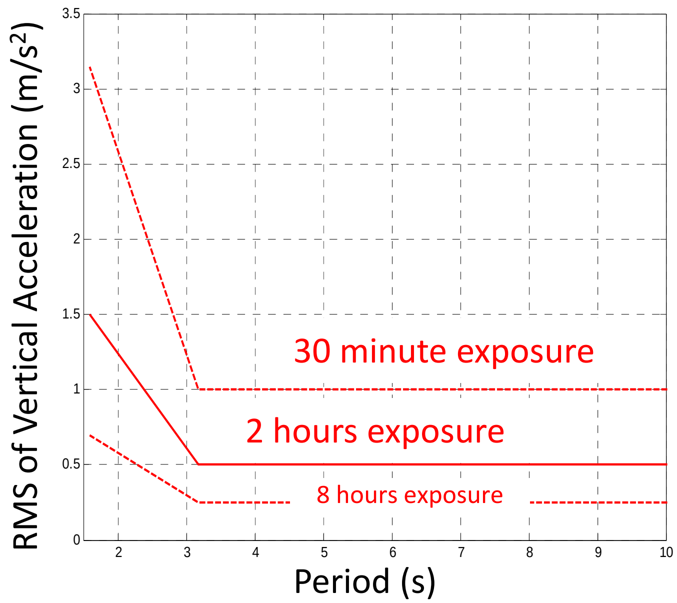
Providing Comfort at Sea

Hydrodynamic Analysis in Operational Sea-states

Criteria to assess passenger comfort:

- RMS of vertical acceleration
- Level of seasickness
  - Function of time of exposure
  - Function of wave period
- Limits provided by

ISO 2631/3



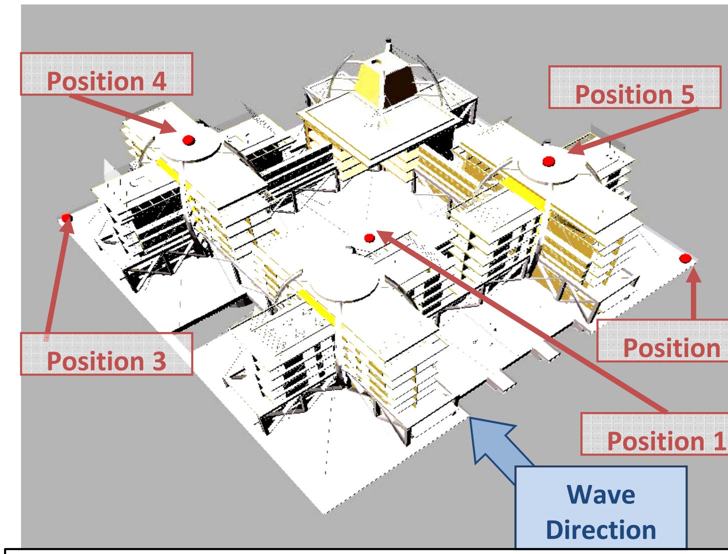
Providing Comfort at Sea

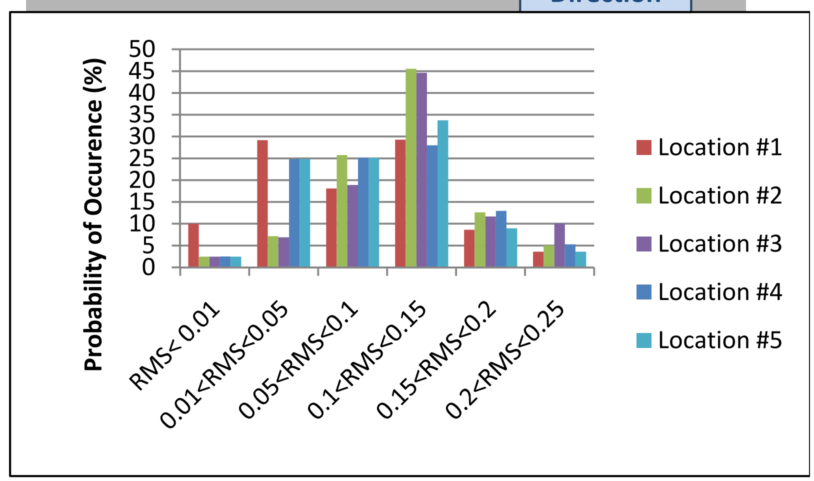
Hydrodynamic Analysis in Operational Sea-states

Assessment of Passenger Comfort:

- 1 hour simulation of operational sea-states
- 5 chosen locations
- Probability of occurrence of RMS based on probability of occurrence of sea-state

Probability of occurrence of sea-sickness is low





Conclusion

- ClubStead : a new design, adapted to long-term life
  - maximum space
  - minimum displacement

  20,900 s.t. displacement,
  With: 7,000 s.t. structural weight
  8,000 s.t payload

- An iterative methodology between architectural and engineering teams

- Future developments:
  - ✓ dynamic structural analysis
  - ✓ effect of 6DOF motions on stay cable tension
  - ✓ cost and weight optimization of design

Q&A

Thank you!

Questions?